THE IMPACT OF EMERGING TECHNOLOGIES IN SUPPORTING URBAN RESILIENCE PLANNING IN CANADA

ORUBA ALWAN BSc (Hons)

A thesis submitted in partial fulfilment of the requirements of
University of Wolverhampton for the degree of
Master of Philosophy

This research was carried out
with the support of the
University of Wolverhampton

March, 2016

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Oruba Alwan: ____________________

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This thesis is proudly dedicated to:

My father, my mom and my aunt, May God bless them all…

Thanks for your endless love, sacrifices, prayers, support and advices

Abstract

Climate change, fast population growth, income inequality and political unrest make resilience a priority for every city in the world. Resilience is what will decide whether cities or indeed countries, preserve their quality of life, economic wealth and, in some cases, their political integrity. The aim of this research is to provide a framework to describe best practices in urban resilience within Canada, which can then serve as a guide for those willing to develop such practices in their own cities. There are four objectives of this study: 1) a critical review of technologies that can be used to support resilience, including big data and advanced computing; 2) completion of a pilot study in Canada, which looks into the approaches to resilience in a developed country; 3) polling of three major cities in Canada to determine their best practices for building resilience; and 4) development of a guide to support resilience implementation measures. Two data collection methods were used, primary and secondary research. Secondary research was used to gather information from Canadian and foreign published academic literature. Primary research was performed with data collected from cities of Mississauga and Toronto, Ontario; Calgary, Alberta; and Vancouver, British Columbia. These primary data were analyzed using factor analysis, as the data collected were textual rather than numeric in nature. The main contribution of this research was the development of a framework for resilience containing five main features: cost, training, software, security and big data; with three components under each feature. The framework proposed can be used as the basis for the development of a toolkit for cities, which could help to evaluate how compliant cities are with implementing resilience measures.

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I love you all.

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Glossary

311 phone – City of Toronto’s phone number for information and reporting and requesting non-emergency city services (City of Toronto, 2016).

3D printing – “... is a process of making three dimensional solid objects from a digital file” (3D Printing.com, 2016).

Autodesk InfraWorks – is a piece of software that allows for “preliminary engineering with data-rick 3D models” and is usually used to design roads, bridges, drainage, and other city infrastructure (Autodesk, 2016b).

Automatic Vehicle Locator (AVL) – a GPS-based or another type of technology used to track a vehicle in real time (Technopedia, 2016a).

Big data – refers to large volumes of data that can be used for analysis and insights generation to support better decision-making (SAS, 2016).

Building Information Modeling (BIM) - “... an intelligence 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure” (Autodesk, 2016a).

Business Intelligence (BI) – “... is an umbrella term that refers to a variety of software applications used to analyze an organization’s raw data” and is also “... made up of several related activities, including data mining, online analytical processing, querying and reporting” (Mulcahy, 2007).

Business Intelligence Platform – “... enable(s) users to build applications that help organizations learn and understand their business” (Vereker, 2011).

Cloud Computing – stands for “... storing and accessing data and programs over the Internet instead of (own)... computer’s hard drive” (Griffith, 2016).

Engagement platform – is an online meeting place where participants can discuss issues, leave comments and feedback, get in contact with others, and interact with stakeholders (The Digital Engagement Guide, 2016).

Enterprise Application Integration (EAI) – "... the use of technologies and services across an enterprise to enable the integration of software applications and hardware systems" (Technopedia, 2016b).

Enterprise Collaboration System (ECS) – "... an information system used to facilitate efficient sharing of documents and knowledge between teams and individuals in an enterprise" (Technopedia, 2016c).

Enterprise GIS – offers the ability of meeting "... organizational objectives through the delivery of geospatial capabilities that include data management, visualization, spatial analysis" (ESRI, 2007).

Enterprise Service Bus – an architecture that "... is a set of rules and principles for integrating numerous application together over a bus-like infrastructure" (MuleSoft, 2016).

ESRI ArcGIS – is an online, cloud-based Geographical Information System used for mapping, analytics, administration, and collaboration within an organization (ESRI, 2016c).

ESRI ArcGIS 3D analyst – desktop extension software – part of ESRI ArcGIS Geographic Information System – for visualization, analysis, and modeling in 3D (ESRI, 2016b).

ESRI ArcGIS Spatial Analyst – ESRI ArcGIS tool for performing of spatial analysis with the data available (ESRI, 2016f).

ESRI ArcMap – is a piece of software used "to create maps, perform spatial analysis, manage geographic data, and share ... results" (ESRI, 2016e).

ESRI CityEngine – is a piece of software used for "... urban planning, architecture, and design" and supports 3D visualization of a city (ESRI, 2016d).

Geographic Information System (GIS) - "... let(s) us visualize, question, analyze, and interpret data to understand relationships, patterns, and trends" (ESRI, 2016a)

Geo-social media – also referred to as "Location-Based Social Networks (LBSN)" is used to create social structure interdependency between individuals who share similar geographical moving patterns and also share similar interests, knowledge, and behaviour (Microsoft Research, 2016).

Green technology – "... encompasses a continuously evolving group of methods and materials, from techniques for generating energy to non-toxic cleaning products" (Green Technology, 2015).

HAZUS – "…a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods and hurricanes. Hazus uses Geographic Information Systems (GIS) technology to estimate physical, economic and social impacts of disasters" (Federal Emergency Management Agency, 2016).

Identity and Access Management (IAM) – "... the security discipline that enables the right individuals to access the right resources at the right times for the right reasons" (Gartner, 2016a).

Infographic – "... is a data-rich visualization of a story or thesis, a tool to educate and inform, a way to build brand awareness and inbound links at half the cost of standard online marketing campaigns" (Customer Magnetism, 2016).

Light Detection and Ranging (LiDAR) – "... is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth" (National Oceanic and Atmospheric Administration, 2015).

MapInfo Pro – is an alternative GIS solution, which is "…a ... 64-bit application with optional raster grid analysis capabilities ... lets (users) create, analyze and share spatial information ..." (Pitney Bowes, 2016).

Master Data Management (MDM) – "... is a technology-enabled discipline in which business and IT work together to ensure the uniformity, accuracy, stewardship, semantic consistency and accountability of the enterprise's official shared master data assets" (Gartner, 2016b).

MetroQuest – is a piece of software designed to collect and analyse insights from thousands of people and informing them of "... the impact of their choices in real time..." as well as get buy-in from these stakeholders for projects run by cities governments (MetroQuest, 2015).

Microsoft Sharepoint – a cloud-computing platform for storing and sharing files with a pre-defined group of people (Microsoft, 2016).

Mobile Ad hoc Networks (MANETs) – "... the replication of wired Internet communication like TCP/IP communications in mobile environments" that allow for "... routing protocols (to) deal with mobility of nodes and continuous topological changes in order to establish and maintain a communication path between a pair of source-destination nodes" (Reina *et al.*, 2015).

Mobile Device Management – "...refers to the control of one or more mobile devices through various types of access control and monitoring technologies" (Technopedia, 2016d).

Open Data – "...is data that can be freely used, re-used and redistributed by anyone - subject only, at most, to the requirement to attribute and sharealike" (Open Data Handbook, 2016).

Open Data Program – government datasets for the Province of Ontario are made available online for free public access (Province of Ontario, 2016).

Peoplesoft – is a software package designed for analysing different datasets within an organization including “human capital management, financial management, supplier relationship management, enterprise services automation, enterprise services automation, supply chain management” (Oracle, 2016).

Pictometry – is a patented process of aerial high-resolution and geo-referenced photographing of buildings and land by EagleView Pictometry in the US (EargleView Pictometry, 2016).

Pictometry Oblique Imagery – “...means the aerial photographs are taken at an angle rather than looking straight down” (Pima County GIS, 2016).

PlaceSpeak – “... is a location-based community consultation platform” (PlaceSpeak, 2016).

POSSE – “...a group of people who were gathered together by a sheriff in the past to help search for a criminal” (Merriam-Webster Dictionary, 2016).

Resilience - The capacity of individuals, communities and systems to survive, adapt and grow in the face of changes, even catastrophic incidents (Havens, 2014).

Radio Frequency Identification (RFID) – “...is the use of radio waves to read and capture information stored on a tag attached to an object. A tag can be read from up to several feet away and does not need to be within direct line-of-sight of the reader to be tracked” (Bar Code Graphics Inc., 2013).

SAP Analytics – is a part of SAP system that offers “business intelligence, predictive analytics, enterprise performance management (EPM), Governance, Risk, and Compliance (GRC)” (SAP, 2016).

Supervisory Control and Data Acquisition (SCADA) – is “... data acquisition and real-time visualization technology... providing solutions to industrial customers and smart city and IoT (Internet of Things) applications for light industrial, commercial, and residential customers” (B-Scada, 2016).

SketchUp – a graphical application for creating professional 2D and 3D for architectural, design, engineering, and construction applications (SketchUp, 2016).

Synthicity – also referred to as “UrbanSim” is “...an integrated platform to share data, design alternative plans as scenarios, simulate the impacts of those plans over time, and visualize outcomes in 3D” for cities and towns (UrbanSim Inc., 2016).

Unmanned Aerial Vehicle (UAV) – “... is an aircraft with no pilot on board” (The UAV, 2016).

Urban resilience – “... is the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience” (Rodin, 2013).

Chapter 1. Introduction

This is a revolutionary time in history. Not only have a new century and a new millennium recently begun, but it is also the time when the global population has reached close to seven billion people with projected continued growth (Engelman, 2011). Today, the majority of these seven billion people live in cities, and the United Nations estimates that close to 100 million people will head to cities from rural areas in the next fifteen years (UNFPA, 2016). Knowing this, the question arises: are cities prepared for this huge inflow of population or are the world's cities headed for an inevitable collapse? (Newman *et al.*, 2009).

> "The 19th century was a century of empires. The 20th century was a century of nation states. The 21st century will be a century of cities" (Curry, 2010).

A possible solution to a potential inevitable collapse lies in intelligent planning and visionary leadership. This will not only help cities meet impending crises, but will also create space for sharing existing initiatives by cities around the world. Rather than responding with fear, cities need to choose hope (Newman *et al*., 2009). The smart city - or at least components of it - will be a model for the world's cities into the future.

1.1. Background

Intelligent planning and visionary leadership distil down to one concept that became famous in the 1970s, but appeared on the city-planning radar centuries before: resilience. Resilience refers to survival skills for cities after a major disaster, be it man-made or a natural disaster (Rockefeller Foundation, 2015a). Resilience is also about the prevention of such catastrophic events or, in cases of their inevitability, about mitigating the outcomes. Resilience includes such strategically important matters for every city as planning, building, and running a city. Resilience encompasses a number of functions that each city performs as a geographical and political entity, including (The Nature of the City, 2015):

- Making sure that all systems run properly and serve the needs of all of the citizens of the city;
- Being aware of the challenges imposed by disasters in modern cities and exploiting the possibilities emerging as a result of recent technological advances;
- Being familiar with and using technologies that can play a critical role in addressing the shortcomings of existing disaster response operations, which have enabled new possibilities for effectively meeting challenges imposed by man-made and natural disasters; and
- Ensuring advances in using big data, databanks and statistical analyses, including: 3D modelling, spotting signals, geographic information systems or GIS, computer-based modeling and simulation, real-time location tracking systems and visualization of complex urban dynamics, so decisions can be more effectively based on the best available knowledge.

1.2. Aim and Objectives

The aim and objectives of this study are described in more detail in the sub-sections below. The ultimate aim of this research is to provide a framework, which can be used as a guide for best practices in urban resilience planning. Based on the foregoing aim, there are four objectives of the study:

- Conduct a critical review of current technologies which can be used to support resilience planning, including big data and advanced computing;
- Perform a pilot study in Canada into the approaches implemented as resilience measures in the country;
- Poll three major cities to determine their best practices regarding resilience; and
- Develop a guide to support resilience implementation measures.

1.2.1. Aim

This aim of this research is to develop a framework that will describe current best practices in urban resilience planning within Canada, which will serve as a guide for city administrators new to resilience planning in implementing such practices in their respective cities. The framework is built using secondary research, which consists of a literature review into historical and more contemporary best practices in resilience, as well as primary research findings collated from studies involving four cities in Canada. The findings of the primary research not only provide a unique Canadian perspective on the question in hand but also provide many of the contemporary resilience practices outlined in the framework. The statistical analysis and the author’s reflection on the information and data gathered help in the creation of a guide for other cities' resilience planning.

1.2.2. Objectives

The follow objectives were the focus of this research:

1. Present a critical review of technologies to support resilience, including big data and advanced computing. As part of this objective such groups of technologies as hardware technologies, including miniaturization and increased processing power; transmission systems, including high bandwidth wireless technologies; and real-time location tracking are discussed in the Literature Review chapter.
2. Perform a pilot study of a Canadian city into what instruments they use as part of their resilience strategy. The realization of this objective is discussed in the Analysis of Evaluation chapter of this thesis, where the results of the factor analysis of the data collected from polling the production and financial capital of the province of Ontario, Mississauga, are laid out.
3. Poll three major cities to determine their best practices for resilience. The results of this poll are presented in the Analysis of Evaluation chapter of this thesis where the information and data gathered are treated using factor analysis. The cities polled are the city of Toronto in the province of Ontario; the city of Calgary in the province of Alberta, and the city of Vancouver in the province of British Columbia in Canada.
4. Develop a set of scalable recommendations concerning the most suitable instruments and approaches to building and maintaining resilience in

every city or town in Canada. This guide is the result of the analysis and author's reflection on the research work, and it is presented in the final chapter of this thesis, Conclusions and Recommendations.

1.2.3. Significance of the Study

Climate change, coupled with fast population growth and a consequent overpopulation in some parts of the world, further aggravated by growing income inequality and recent political unrest in more than one geographical region in the world, makes resilience one of the top or indeed the top priority for every city in the world (UNISDR, 2016). Resilience is what will decide whether cities, sometimes even whole countries, preserve their quality of life, economic wealth and, in some cases, their political integrity. For example, a relatively recent flood in the province of Alberta Canada proved to be a major disaster for the City of Calgary and a number of other cities in 2013 (Environment and Climate Change Canada, 2014). Annual devastating floods in Winnipeg, Manitoba (Public Safety, 2015), annual highly damaging wild fires in British Columbia and Quebec (Natural Resources Canada, 2016), and tropical storms in the Maritime Provinces (Environment and Climate Change Canada, 2016) are just some of the major natural disasters that require city governments to exercise resilience in Canada and around the world (Canadian Urban Institute, 2015; UNISDR, 2016). Today resilience is one of the most interesting topics to study when it comes to city planning and administration (Canadian Urban Institute, 2015). It is also the most important topic under discussion for Canadian cities and other cities around the world (UNISDR, 2016).

1.3. Research Justification

Despite the fact that resilience has been popular since the 1970s and the notion itself was introduced back in the seventeenth century, resilience is more alive today than ever. For some cities, proper resilience management is a matter of life or death. Fortunately, this is not the case in Canada, but how different is the situation here compared to other parts of the world? (Resilience, 2015). Little research is available on this topic. This study is focused on resilience in Canada, best practices and how these can serve as a guide for cities in other countries in different parts of the world. This research fills a gap in knowledge concerning resilience in the northern part of North America that is Canada, which has been ignored due to the fact that the USA is better known for best practices, in any subject, when it comes to North America (Meybeck et al., 2012).

1.4. Outline of Methodology

For the purpose of this research, two data collection methods were used, primary and secondary research. The information for the Literature Review chapter was gathered using secondary research into previously published academic literature. Both Canadian and foreign academic literature were drawn upon and, where necessary, investigative journalists' articles from reputable publications were used to complement the findings and the analysis. Primary data were collected from cities' representatives all over Canada, specifically from the cities of Mississauga, Toronto, Calgary, and Vancouver in the respective provinces of Ontario, Alberta, and British Columbia. These primary data were analysed using factor analysis, as the data collected were textual rather than numeric in nature. Finally, all findings were processed and integrated into the Conclusions and Recommendations, where a guide for resilience was developed.

1.5. Key Findings

The key findings of the research include:

- Historical and current best practices in resilience in terms of technologies being used and stakeholders' participation,
- Preliminary insights into what resilience means in Canada using the pilot study in the City of Mississauga,
- Fully developed insights into what resilience means in major Canadian cities and the types of technologies being used to facilitate resilience, using the study of the cities of Toronto, Calgary, and Vancouver,
- A guide into how resilience can be applied in other cities in the world, based on the results of the analysis of secondary and primary data.

1.6. Guide to the Thesis

This thesis consists of five chapters. The Introduction chapter presents the problem to the reader and explains the importance of the notion of resilience as well as the aim and the objectives of the study performed. The Literature Review chapter provides an overview of the historic and current best practices from around the world. The Methodology chapter describes and justifies what data collection and analysis methods were used to gather and process information and data for the study. The Analysis of Evaluation chapter summarizes the poll results using factor analysis and presents insights into the data gathered from the four cities polled. The Conclusions and Recommendations chapter presents a guide to resilience based on the analysis conducted in the previous chapters.

1.7. Summary

This chapter presents a background to the study, the research aim and objectives, why the author is interested in researching the topic, global resources that were used in writing this thesis. The chapter also presents research justification, briefly outline the methodology of the study that is further described in chapter three of the thesis. The chapter further denotes key findings that were expected to obtain at the beginning of the research. The chapter concludes with a guide to the thesis where each part of the thesis is described briefly. The purpose of this chapter is to introduce the reader to this thesis work, explain what each part of thesis presents and supply the reader with sufficient information to find what they are looking for in the thesis.

Chapter 2. Literature Review

2.1. Overview

McKibben (2012) provides a detailed discussion on why planning is important for the stability and future development of major cities. In this article, the values of the main factors that may affect the stability of any city, which are temperature, carbon dioxide, and oil reserves, are discussed. The paper concludes that many of the negative impacts and consequences that cities are confronting are the result of human activity. Globally, more people live in urban areas than in rural areas, and by 2050, 66 per cent of the world's population is projected to be urban (United Nations, 2014). The implications of this shift in the population distribution will result in an unprecedented situation: more people will be living in urban areas than outside them. As a comparison, in 1913 only 10% of people were living in cities (United Nations, 2015).

Desouza & Flanery (2013) point out that half of the people on the planet already live in cities. The authors project that by 2050 around 75% of the world's population will live in cities. The fact that half of the world's inhabitants now live in cities and that in the next twenty years the number of urban dwellers will swell to an estimated five billion people, will increase pressure on already inefficient transportation systems and poorly designed buildings. Thus, many cities will increase the quantity of fossil fuels burned and the amount of greenhouse gases emitted.

The situation highlighted here leads to the question: *Are the world's cities headed for an inevitable collapse*? (Newman *et al.*, 2009)

Newman *et al.* (2009) discuss the goal of intelligent planning and visionary leadership, which they believe is to help cities meet impending crises, and look to existing initiatives in cities around the world. A philosophical perspective is to respond with hope and not with fear. First, the present situation regarding the use of oil and its contribution to climate change is described and then four possible outcomes for cities are portrayed:

1. Collapse
2. Ruralised
3. Divided
4. Resilient

In response to these scenarios, it should be possible to develop a new sustainable urbanism that can replace the present carbon-consuming urbanism. A detailed example addresses how new transportation systems and buildings can be feasibly developed to replace the present low efficiency systems. (Newman et al., 2009)

According to Rodin (2013), resilience, just like sustainability, represents an abstract concept. Therefore, it can be difficult to determine specific ways to plan for resilience. Resilience is a way of thinking that calls for more strategy about planning, building and running cities. This ensures that the city's systems are working for all citizens. Spending huge amounts of money rebuilding and repairing after emergencies will never allow advancement in any of the other goals of a city, such as preparing for disease outbreaks, and mitigating social inequities or unemployment. It is critical that resilience is seen not just as something useful after a shock, but as something actively pursued by governments, private enterprises, and citizens working together in moments of need and in times of relative calm, not just for the benefit of one city, but for all cities. A response to vulnerabilities is not a new concept and, throughout history, it has been a big concern for cities. There is a long record of resilience responses, such as the aqueduct systems and underground subways. Today, though, the global community is experiencing these shocks and disruptions on a near weekly basis. Some examples are Boston (USA), Istanbul (Turkey), San Jose (Costa Rica), Athens (Greece), Budapest (Hungary), and Colorado Springs (USA). All these cities are from different regions, with different demographics, geographic terrains, and political systems. But they all share one thing in common: in 2013 they each experienced at least one major disruption Rodin, 2013):

- Bombings
- Violent protests
- Earthquakes
- Financial ruin
- Unprecedented flooding
- Devastating wildfires

The Rockefeller Foundation (2015b) discusses that it is not possible to predict when or where the next shock will hit. But that it is a fact that shocks will come. They explain that shocks will likely only continue to increase in frequency, intensity, and impact for at least three reasons:

1. Urbanization
2. Globalization
3. Climate change

Climate change adds pressure on both urbanization and globalization challenges. In fact, when these three factors are interacting synergistically, they present the greatest threats and disruptions for populations. All cities deal differently with these shocks.

2.2. Resilience: Terminology

Resilience is defined by Havens (2014) as: “The capacity of individuals, communities and systems to survive, adapt and grow in the face of changes, even catastrophic incidents.” In other words, resilience is about making people, communities and systems better prepared to withstand catastrophic events, either natural, climate change-driven, or man-made, learn from the events, and adapt to be better able to deal with similar future events or issues. At the same time that the term resilience is defined, it is helpful to discuss what resilience is not. It is not a solution to the last problem.

> "What the last problem looked like; you know it very well. In a span of less than 215 days, we endured Hurricane Sandy, a horrific shooting at Sandy Hook Elementary School, bombings at the Boston Marathon, a massive fertilizer factory explosion in Texas, and severe flooding and tornadoes in various parts of the country" (Abdul-Matin, 2013).

Resilience is not just about climate change or adverse weather. It is about the shock and awe of the unknown and about what to do before and after those disruptive events. Resilience is also not a trait people are born with (Resilience, 2015). While the recovery of New Jersey versus the recovery of New Orleans after Hurricane Katrina should give one elements to reflect upon, there is a natural question: Are certain communities and people inherently better at managing shocks and interruptions than others? (Havens, 2014).

The answer to this question rests on the fact that any skill can be learned. Thus, it is possible to teach people to recover, persist, and thrive during an emergency; that is, the learning of how to be resilient in the lulls between the shocks. As an example, after 9/11, property owners were so worried about attacks from the air that they buried their generators underground, where they were submerged by the storm surge during Sandy. Resilience is not an innate human quality that bubbles up in times of stress, as it is often talked about, for example, after the Boston bombings. And it is not an emergency response after a disaster has hit (Havens, 2014).

Resilience is what is built in those moments between a catastrophe and the next big disruption; it's a skill that can be learned, and a quality that can be adapted, from toughening up building codes in San Francisco, to withstand the shocks of the next earthquake, to the creation of Evacuspots in New Orleans, to ensure a speedy evacuation of residents ahead of future storms (Rodin, 2013). Building resilience is critical to protecting the most vulnerable populations, those who typically live in the most easily impacted areas and who are least likely to have savings stashed away or insurance to protect them in case of a disaster

(Rodin, 2013). This kind of situation is present in developing countries, where already overcrowded slums will nearly double in population to 2 billion people, putting strains on already fragile ecosystems and hindering the ability of these areas to respond to shocks and recover from them (Rodin, 2013).

Krings (2015), from the German Federal Office of Disaster Assistance, is focused on the major adaptive strategies Germany is putting into action against climate change. Natural disasters, human failures and other types of disasters (terrorism, war and crime) are the major issues the agency is concerned with. This study concludes by explaining the concept of prioritization: “Which situation is tolerable and which not?” and “what are the minimum services to be provided when the population is under risk?” Krings (2015).

The definition of resilience is the quality of being able to resume its original shape, or the ability to recover quickly. “Resilience is the capacity of a system to continually change and adapt (to new conditions) yet remain within critical thresholds” (Stockholm Resilience Centre, 2015). Resilience reflects the ability to persevere in the face of an emergency, to continue the core mission despite daunting challenges, and is as appropriate to discussions about Venice's rising tides as Medellin's corruption, Detroit's unemployment, and Budapest's floods (Krings, 2015).

Resilience provides a practical framework to identify climate sensitivities and prioritize opportunities to promote resilience. Resilience is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption of some sort.

> "Resilience is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption" (Resilient Design Institute, 2015).

Resilience is not simply an emergency response; it is how people survive and get stronger even when things are very tough (Abdul-Matin, 2013).

2.3. Urban Resilience

Desouza & Flanery (2013) propose that “our future is an urban future that is resilient.” As of 2010, half of the world’s population dwells in urbanized areas, and of those, 3.5 billion people, 38%, live in large urban agglomerations or mega-cities. From 2005 to 2010, the world’s urban population increased at a rate of 1.9% annually (United Nations, 2011). Rapid urbanization and growing mega-cities point to a need for smarter and more resilient cities that possess the capacity to withstand the shocks of population growth, world economic crises, rapid demographic shifts in population, and environmental catastrophes. In addition, resilience must also be displayed in terms of events that have a more long-term horizon, such as when cities are in decline. Resilience in terms of cities generally refers to the ability to absorb, adapt and respond to changes in an urban system. Resilience shares three other key contemporary urban goals:

1. Sustainability
2. Governance
3. Economic development

This definition of sustainability goes hand in hand with the definition of sustainability and thus requires an explanation of the distinction between the two. Kim & Lim (2016) discuss urban resilience as the capacity of cities to exercise sustainable development and progress in the face of climate change. The authors further describe resilience as a type of sustainability where cities can withstand the impact of climate change and strive further. Chelleri & Olazabal (2012) state that resilience is about how people or cities deal with change, and that resilience was a reflection of sustainability in the past in the way that current generations must ensure there were sufficient resources for the needs of future generations. According to the authors, resilience was first introduced in a new light in 2002, and in the same year, it was recognized that resilience and sustainability were about

> “...the precautionary principle regarding resource use and emerging risks, the avoidance of vulnerability and the promotion of ecological integrity in the future” (Chelleri & Olazabal, 2012).

Taking this similarity into account, the authors further conclude that

> “...resilience can be see as a necessary approach to meet the challenge of sustainable development” (Chelleri & Olazabal, 2012).

O’Brien (2012) states that resilience and sustainability are a subject of risk management discipline and require a collaborative effort from policymakers and policy-enforcers.

The above scholars tend to agree that sustainability and resilience are part of one and the same – the ability of people or cities to sustain and overcome change, where most of the time this change is negative and is caused by a natural or man-made disaster. In the opinion of the author of this thesis, sustainability is a somewhat utopic notion as in the twenty-first century it is clear that most or all of the resources available to the humanity today are finite. Thus, sustainability should not be about not using the resources but rather avoiding waste. In this way, humanity might get as close it possibly can to becoming sustainable. Resilience on the other hand is a real notion that is about perceiving, adapting, surviving change, and becoming stronger as a result. Resilience is what today’s cities can and must practice, whereas sustainability should be adapted to a more doable concept of reducing waste. It is this thesis author’s opinion that resilience and sustainability are different notions and although there are similarities to them, the real-life nature of the first and the utopic nature of the second does not allow them to become neither completely similar nor fully interchangeable.

Urban resilience is working to adapt and respond to changes in an urban system. 100 Resilient Cities (Rodin, 2013) has a unique and broad view of how urban resilience is defined: the capacities of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kind of chronic stresses and acute shocks they experience.

- Shocks are typically considered *single event* disasters: fire, earthquakes and floods.
- Stresses are factors that pressure a city on a daily or a reoccurring basis: chronic food and water shortages, an overtaxed transportation system, or a high unemployment rate.

In order to function effectively, the city system and component systems need to have certain characteristics, while the changing environment refers to short- and long-term changes, that is, both shocks and stresses, which may be caused by a wide range of hazards, threats and trends. This definition recognises that the urban environment is intrinsically changeable and allows for the city system to transform in order to function effectively in the face of uncertainty.

2.4. Urban Resilience: Challenges

There is a big dispute between the thinking of urban economists and environmental economists regarding whether a collision between climate change and urbanisation is in fact unavoidable if governments continue to take no action (United Nations, 2011). The root of the problem is simple: the world's cities account for 70% of climate changing emissions (United Nations, 2011); however, they cover only 2% of the planet's land mass (United Nations, 2011). It is estimated that 59% of the world's population (United Nations, 2011) will be living in urban areas by 2030 (United Nations, 2011) coupled with the fact that every year the number of people who live in urban areas grows by 67 million (United Nations, 2011), with developing countries accounting for 91% of this trend (United Nations, 2011). The extreme densities of these areas create vulnerability consequences, including increases in the intensity of frequent warm spells, heat waves as well as extremely high sea levels (United Nations, 2011). Urban areas are naturally energy-intensive due to the increased use of transportation, heating and cooling and economic activity to generate income (United Nations, 2011). However, it is because of these dependencies that future populations will be stripped of their assets and livelihoods, due to future climate changes affecting water supply, physical infrastructure, transport, ecosystem goods and services, and energy provision (United Nations, 2011).

According to the Rockefeller Foundation (2015b), the top five shocks are:

1. Coastal and rainfall flooding,
2. Earthquakes,
3. Tropical storms including hurricanes and typhoons,
4. Heat waves, and
5. Landslides.

According to the Rockefeller Foundation (2015b), the top five stresses are:

1. Aging infrastructure,
2. Drought and water shortages,
3. Environmental degradation,
4. An overtaxed/underdeveloped/underfunded public transportation system, and
5. Sea level and coastal erosion.

There is a belief shared by many that resilience may not live up to its promise for a variety of reasons, including (Rockefeller Foundation, 2015b):

1. The potential for narrow interpretations,
2. A selective or limited understanding of what can be a relatively abstract concept, and
3. A lack of quantifiable metrics for evaluation purposes.

Northwestern University (2015) concludes that to address challenges imposed by disasters in modern cities and to exploit possibilities emerging as a result of recent technological advances, the following steps need to be taken:

- Advance the use of data management, geographic information, computer-based modeling and simulation, and visualization of complex urban dynamics so that decisions can be more effectively based on the best available knowledge,
- Conduct research that leads to better policies related to urban climate change mitigation and adaptation, and
- Engage the research and practitioner communities in dialog so both sides truly learn from each other about processing power, transmission systems and real-time location tracking and data collection.

Alinova (2015) discussed the very real threat of resilience being adopted and applied in name only; that there is a real risk that in the rush to measure resilience and develop quantitative metrics for comparative purposes, what is actually measured may represent the same things that have long been monitored and measured but are now being packaged in the language of resilience to meet the demand. The fact remains however, that resilience will and already is, being measured (Quinlan, 2014).

2.5. Technologies for Resilience Management

Technologies can play a critical role in addressing shortcomings of existing disaster response operations (Wattegama, 2013). Recent technological advances include:

- In hardware: e.g. miniaturization and increased processing power;
- Transmission systems: e.g. high bandwidth wireless technologies; and
- Real-time location tracking and data collection systems.

These innovations have enabled new possibilities for effectively meeting challenges imposed by man-made and natural disasters (Wattegama, 2013).

2.5.1. Geographic Information Systems (GIS) for Disaster Response

Geographic Information Systems (GIS) play a critical role in spatial analysis, which can help develop high levels of situation awareness and facilitate critical decision-making. GIS can be used during all four phases of disasters, including preparedness, response, recovery, and mitigation. During the preparedness phase, spatial data and geospatial analysis services can be prepared and deployed. Real-time data collection, integration, and analysis can be performed based on GIS during the response phase, while during the recovery phase large-scale spatial planning and progress monitoring for repair of infrastructure and housing can be executed (Peña-Mora *et al.*, 2004).

During the mitigation phase, GIS simulation models and cost analysis can be studied through visualization and comparisons drawn to identify alternative disaster mitigation plans for future disasters. Prior to disasters, resources, facility locations, and road network data are geo-coded into geospatial databases. After the disaster, the application takes destinations and traffic conditions as inputs, and analyzes the updated road network data for optimal allocation routes and resource distribution decisions. The application is automated for easy and efficient use under stressful and complex conditions. Moreover, different optimization models can be plugged into the system for different scenarios for resource allocation. First, spatial data critical to disaster response is prepared prior to disasters. During disasters, graphical representations of collected spatial information, traffic conditions and disaster sites, is done using GIS. Also, GIS facilitates critical decision-making and emergency response planning through services such as facility location selection and emergency route finding for optimal resource allocation (Kolbe *et al.*, 2011).

2.5.2. RFID/Mobile Ad-hoc Networks for Building Assessment

The next generation of disaster resilient Radio Frequency Identification (RFID) technology was employed to support an assessment of building conditions and the status of rescue operations (Aziz et al., 2009).

The rationale of tracking building conditions during Urban Search and Rescue operations is twofold. First, responders entering buildings need to know which parts of a building are structurally safe and free of hazardous materials.

Second, identifying buildings that are safe for re-occupancy can reduce overall chaos and allow staging areas for people displaced from their homes. Apart from the structural assessment markings, building assessments also include information like potential victim location and number of victims rescued. In existing practice, building assessment information is posted on buildings with the help of spray paint. Recording assessment information using spray paint has many limitations, including poor visibility in foggy/smoky conditions. Also, this information is not recorded in computers, resulting in a lack of overall situation awareness about the search and rescue process. Forms containing critical building assessment information are submitted only towards the end of an operational cycle, causing delays in communication. However, for optimal resource allocation, it is imperative that decision-makers are made aware of site conditions as quickly as possible. During disasters such real-time access is often made difficult because of a failure of pre-existing infrastructures, such as telecommunication networks (Aziz *et al.*, 2009).

2.5.3. Building Black-Boxes

Building black-boxes are ruggedized and serve as disaster resistant information storage hubs, which are embedded in buildings to support building assessment during disaster response operations. Building black-boxes serve to achieve a two pronged objective: first, to store static building information, such as the building information model, building drawings, historic maintenance and operations data; and second, to provide dynamic building information through disaster resilient sensors, such as temperature, humidity, stress/strain in structural elements as well as visual sensors locating personnel/victim locations inside a building. System testing is done to meet disaster resilience, and secure communications and resilience requirements. Regular backups of information stored in building black-boxes is done at secure data mirroring centers and emergency offices in order to ensure building information availability during an incident response. In cases where regular communication infrastructure is not available after disaster events, engineers can access information stored in a black-box using mobile ad-hoc networks or through a satellite up-link (Pena-Mora *et al.*, 2004).

2.5.4. Reconstruction During or Post Disaster Built Environment Using Real-Time Images or Video Stream Data from a Disaster Site

Visualization of the built environment using photographs and videos allows first responders and decision-makers - regardless of their level of knowledge and expertise – to understand the spatial constraints of the disaster site and explore rescue and recovery operation alternatives. In addition, during disaster response and recovery operations, there is limited time to assess the stability of the disaster site. Therefore, reconstruction of the scene based on images could become a good source for during- and post-disaster site stability assessment and act as a good communication tool among first responders (Behzadan & Kamat, 2008).

2.5.5. Building Information Modeling, BIM

Building Information Modeling (BIM) is defined as

> "... an intelligence 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure" (Autodesk, 2016a).

BIM can play a crucial role in releasing the bottleneck that often stops designers' smart ideas from reaching clients. BIM could improve procurement practices and opportunities for architects and other suppliers to contribute to innovation in construction. A BIM carries all information related to the building, including its physical and functional characteristics and project life cycle information, in a series of "smart objects." As a result, quantities and shared properties of materials can be readily extracted. Scope of work information can be easily isolated and defined. Systems, assemblies, and sequences can be shown in a relative scale with the entire facility or group of facilities. The construction documents, such as drawings, procurement details, submittal processes and other specifications, can be easily integrated (Miettinen & Paavola, 2014).

The BIM retrieved from a black-box allows the pre-disaster situation to be known. Superimposing the reconstructed scene on the pre-disaster virtual model environment, allows photographs and video snapshots to be registered within the virtual environment (Miettinen & Paavola, 2014).

There is a growing interest in the integration of BIM and Geographic Information System (GIS). The latter

> "... let(s) us visualize, question, analyze, and interpret data to understand relationships, patterns, and trends" (ESRI, 2016a)

However, most of the research is focused on importing BIM data into GIS applications and vice versa. Real integration of BIM and GIS is using the strong parts of GIS technology in BIM, and of course the strong parts from BIM technology in GIS (Kolbe, 2011).

2.5.6. Augmented Reality Techniques for Disaster Visualization

Once the camera angle is known for each image, the video stream or each photograph would be registered with the 3D model. This, in turn, creates an Augmented Reality environment wherein the pre-disaster virtual model is superimposed with post-disaster images (Golparvar-Fard et al., 2009).

2.5.7. 3D City Model

During rescue operations, there is little time for a rigorous structural analysis and limited time to decide the remaining stability of the building and/or the temporally shoring measures required (McGuigan, 2002). The large variety in structural typologies and different levels of damage make it difficult to model simple patterns for building behaviour. Light Detection and Ranging techniques could provide a quick way to gather building data from the disaster scenario and give planners tools to improve building assessment models (Cheuk & Yuan, 2009). Laser technologies serve as a valuable tool to gather real-time information in the response phase of an extreme event (Kemec *et al.*, 2015).

2.5.8. Robust Wireless Communication Networks

The ways to improve collaboration and coordination in a disaster response effort have been highlighted in various studies (O'Brien, 2012; Chatterjee et al., 2010; Waugh & Streib, 2006; GSMA, 2013). Also the pitfalls related to collaboration, such as lack of trust, information sharing, communication and coordination, have been well documented (Carlson, 2014; Technical Response Planning, 2012). In the hours and days following a major disaster, communication is often limited because the existing infrastructure may be destroyed or the event may have occurred in an area without infrastructure. Voice services may be severely restricted. Challenges imposed by disasters emphasize that a collaboration medium provides some missing attributes, such as high availability, improved transmission capability, and appropriate information dissemination (Oh, 2010). To achieve these goals, a reliable and transparent Mobile Ad-hoc Space for Collaboration (MASC) was developed to support collaboration among first response organizations and leverage civil engineers' role during disaster response and recovery operations (Aldunate *et al.,* 2005). MASC was tested through software simulations in a search and rescue exercise at the Illinois Fire Service Institute. The results showed that it was possible to build a system for traditional teams of first responders which exhibited 98% of availability in square areas where the side length is about three times the wireless communication range (Aldunate *et al.,* 2005). Furthermore, the search and rescue exercise allowed the research to confirm results found through simulation runs about availability and to demonstrate that MASC is also portable among different devices, transparent to first responders, and able to adequately manage and disseminate information in disaster scenarios. Such results demonstrate the appropriateness of Mobile Ad-hoc Space for Collaboration systems. Currently, the ways to scale up MASC for a large set of response teams is being explored with tools such as Mobile Communication Bridges (Peña-Mora *et al.,* 2004) that would allow responders to communicate reliably and securely.

2.5.9. Big Data

Resilience (2015) lists 7 principles for Big Data when managing a resilience project. These seven core principles serve to guide data projects to ensure they are socially just, encourage local wealth- and skill-creation, require informed consent, and be maintainable over long timeframes:

1. Open Source Data Tools - Wherever possible, data analytics and manipulation tools should be open source, architecture independent and broadly prevalent (R, Python, etc.). Open source, hackable tools are generative, and building generative capacity is an important element of resilience. Data tools that are closed prevent end-users from customizing and localizing them freely. This creates dependency on external experts which is a major point of vulnerability (Uri-Bar, 2013; Henschen, 2014). Open source tools generate a large user base and typically have a wider open knowledge base. Open source solutions are also more affordable and by definition more transparent. Open Data Tools should be highly accessible and intuitive for use by non-technical users and those with limited technological access in order to maximize the number of participants who can independently use and analyze Big Data (Davenport, 2014; Kuketz, 2012).

2. Transparent Data Infrastructure - Infrastructure for data collection and storage should operate based on transparent standards to maximize the number of users that can interact with the infrastructure. Data infrastructure should strive for built-in documentation, be extensive and provide easy access. Data is only as useful to the data scientist as her/his understanding of its collection is correct. This is critical for projects to be maintained over time, regardless of team membership; otherwise, projects will collapse when key members leave. To allow for continuity, the infrastructure has to be transparent and clear to a broad set of analysts – independent of the tools they bring to bear. Solutions such as hadoop, JSON formats and the use of clouds are potentially suitable (Opendata.cz, 2016);

3. Develop and Maintain Local Skills - Make “data literacy” more widespread. Leverage local data labor and build on existing skills. The key and the greatest constraint to effective data solutions remain human skill/ knowledge, which needs to be retained locally. In doing so, consider cultural issues and language. Catalyze the next generation of data scientists and generate new required skills in the cities where the data is being collected. Provide members of local communities with hands-on experience; people who can draw on local understanding and socio-cultural contexts. Longevity of Big Data for Resilience projects depends on the continuity of local data science teams that maintain an active knowledge and skills base that can be passed on to other local groups.

This means hiring local researchers and data scientists and getting them to build teams of the best established talent, as well as up-and-coming developers and designers. Risks emerge when non-resident companies are asked to spearhead data programs that are connected to local communities. They bring in their own employees, do not foster local talent over the long-term, and extract value from the data and the learning algorithms that are kept by the company rather than the local community (Maycotte, 2014);

4. Local Data Ownership - Use Creative Commons and licenses that state that data is not to be used for commercial purposes. The community directly owns the data it generates, along with the learning algorithms (machine learning classifiers) and derivatives. Strong data protection protocols need to be in place to protect identities and personally identifying information. Only the "Principle of Do No Harm" can trump consent, as explicitly stated by the International Committee of the Red Cross's Data Protection Protocols (ICRC, 2013). While the ICRC's data protection standards are geared towards humanitarian professionals, their core protocols are equally applicable to the use of Big Data in resilience projects. Time limits on how long the data can be used should be transparently stated. Shorter frameworks should always be preferred, unless there are compelling reasons to do otherwise. People can give consent for how their data might be used in the short to medium term, but after that, the possibilities for data analytics, predictive modelling and de-anonymization will have advanced to a state that cannot at this stage be predicted, let alone consented to (Resilience, 2015);

5. Ethical Data Sharing - Adopt existing data sharing protocols like the ICRC's (2013). Permission for sharing is essential. How the data will be used should be clearly articulated. An opt-in approach should be the preference wherever possible, and the ability for individuals to remove themselves from a data set after it has been collected must always be an option. Projects should always explicitly state which third parties will get access to data, if any, so that it is clear who will be able to access and use the data. Sharing with NGOs, academics and humanitarian agencies should be carefully negotiated, and only shared with for-profit companies when there are clear and urgent reasons to do so. In that case, clear data protection policies must be in place that will bind those third parties in the same way as the initial data gatherers. Transparency here is key: communities should be able to see where their data goes and a complete list of who has access to it and why (Resilience, 2015);

6. Right Not To Be Sensed - Local communities have a right not to be sensed. Large scale city sensing projects must have a clear framework for how people are able to be involved or choose not to participate. All too often, sensing projects are established without any ethical framework or any commitment to informed consent. It is essential that the collection of any sensitive data, from social and mobile data to video and photographic records of houses, streets and individuals, is done with full public knowledge, community discussion, and the ability to opt-out. In essence, this principle seeks to place "Data Philanthropy" in the hands of local communities and in particular individuals. Creating clear informed consent mechanisms is a requisite for data philanthropy (Resilience, 2015); and

7. Learning from Mistakes - Big Data and Resilience projects need to be open to face, thesis, and discuss failures. Big Data technology is still very much in a learning phase. Failure and the learning and insights resulting from it should be accepted and appreciated. Without admitting what does not work, the community is not learning effectively. Quality control and assessment for data-driven solutions is notably harder than comparable efforts in other technology fields. The uncertainty about the quality of the solution is created by the uncertainty inherent in data. Even good data scientists are struggling to assess the upside potential of incremental efforts on the quality of a solution. The correct analogy is more of a craft rather than a science. Similar to traditional crafts, the most effective way to excellence is to learn from one's mistakes under the guidance of a mentor with a collective knowledge of experiences of both failure and success (Pena-Mora *et al.*, 2004).

2.6. Assessments

Urbanisation is one of the great driving forces of the twenty-first century. Cities generate both productivity and creativity, and the benefits offered by high-density living and working contributes to sustainability. Cities comprise multiple components, forming both static and dynamic systems that are interconnected directly and indirectly on a number of levels. Bringing together large numbers of people within a complex system can lead to vulnerability from a wide range of hazards, threats and trends. The key to reducing this vulnerability is the identification of critical systems and determination of the implications of their failure and their interconnectivities with other systems (da Silva *et al.*, 2010).

2.7. Summary

This chapter presented literature review as pertaining to the thesis. The chapter defines what resilience and urban resilience are, the major challenges that cities face when building a resilience strategy. The chapter presents a number of technologies that are commonly used for resilience planning in contemporary cities. These include Geographic Information Systems for disaster response, building black boxes, Building Information Modeling, augmented reality techniques for disaster visualization, 3D city models, big data, wireless communication networks, and reconstruction of during and post-disaster built environment using real-time images and video stream data from a site of disaster.

This chapter presents resilience and how resilience is planned and managed by cities in the twenty-first century. In the following chapters, this information is used to present, explain and compare the findings from the qualitative research conducted for the purpose of this thesis.

Chapter 3. Methodology

3.1. Introduction

As highlighted in Chapter 1, the primary aim of this research is to develop a new guidance framework on best practices for urban resilience planning within Canada. In order to achieve the objectives stated in Section 1.2, a robust qualitative research methodology was developed. The following sections describe the research methodology employed in this study and the development of the questionnaire instrument.

3.2. Overall Research Methodology

Fellows and Lui (2008) point out that a rigorous methodology is core to any piece of research undertaken and is fundamental to the development of new knowledge. Furthermore, Farrell (2011) discusses the strategic nature of the overall research methodology and how this varies from the actual method undertaken to collect primary research results. Bloomberg & Volpe (2008) describe research methodology as a summary of ten elements: introduction, research sample, overview of information sought, overview of research design, methods of data collection, data analysis, ethics of the research, trustworthiness of the research, limitations of the research, and summary. This part of this thesis describes eight of the ten elements presented above, with the other two elements described in the Introduction and Summary parts of this chapter. Combining these philosophies together, a generic three phase strategy was adopted to underpin the proposed research methodology used in this study.

These phases included detailed review, primary data collection and synthesis and analysis of data to develop a framework (Naoum, 2013). This approach is highlighted in Figure 3.1.

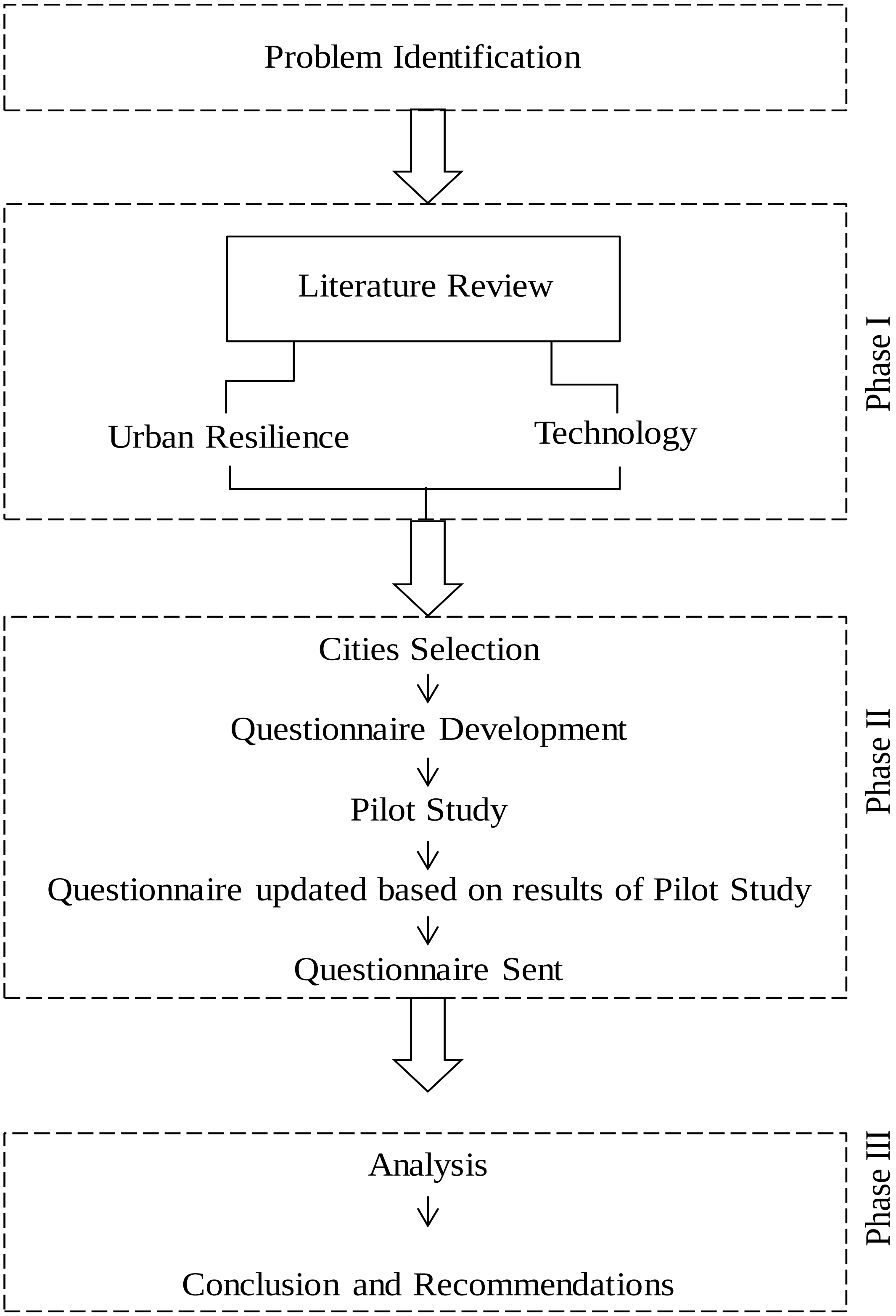

Figure 3.1. Flow Diagram of the Research Followed to Study the Resilience Processes of Selected Cities.

To achieve the goal of the study and to satisfy the objectives, a qualitative research method was chosen. The goal and the objectives require detailed data to be gathered from each participating city, hence detailed questionnaires were developed. As this information is not readily available online or elsewhere, it was necessary to poll the cities' personnel. Because this method required cities to share their, sometimes privileged, information, only a few cities were willing to participate. Four city representatives were contacted and only three of them responded to the questionnaire fully. Finally, due to the fact that a large amount of textual and qualitative information needed to be processed, only these four cities were included, with one of them being a pilot study.

3.3. Phase 1 - Review

A key stage to any research project is the development of a full understanding of the current status of knowledge, which places the current work into the existing context (Levis and Ellis, 2006). Farrell (2011) further explains that the review serves to not only determine what research has previously been undertaken but also identify gaps in current knowledge. According to Levis and Ellis (2006) an effective literature review will meet the following 5 goals:

- Help the researcher to understand the existing body of knowledge, including 'what is already known?' and 'what is needed to be known?'
- Provide a solid theoretical basis for the proposed study.
- Substantiate the presence of the research problem.
- Justify that the proposed study contributes something to the existing body of knowledge.

- Frame the validity of the research methodology, proposed approach, goals and research question.

The critical review undertaken (Chapter 2) allowed understanding of the prominent research in the field of resilience and the existing and emerging technologies available to support resilient cities. When combined with the primary data established from this research, a framework can be constructed to bring together the most appropriate approaches to urban resilience (Seuring and Müller, 2008).

3.4. Phase 2 – Primary Data Collection

To collect the primary data for the analysis, the following steps were undertaken:

Step 1. Selection of cities for the study

Step 2. The pilot questionnaire was developed

Step 3. The pilot study was performed

Step 4. A final questionnaire was prepared using feedback from the pilot study and issued to the subject cities

3.4.1. Step 1 – City Selection

At the initial stage of the project and after the literature review, the cities which were to be the subjects of the research were selected. According to Grosvenor's (2014) research thesis "Resilient Cities," the world's ten most resilient cities list is topped by Toronto, Vancouver, and Calgary, followed by five American cities, the capital of Sweden, and the capital of Switzerland. The ranking is based on such elements as "vulnerability score, adaptive capacity score, highest forecast population growth." The cities of Calgary, Toronto, and Vancouver are also considered to be "the least vulnerable" worldwide based on their "climate, environment, resource, infrastructure, community." According to the same study, Toronto is also considered to be the second "most adaptive" city, taking into account such elements as governance, institutions, technical and learning elements, planning systems, and funding structures (Grosvenor, 2014).

The cities of Toronto, Calgary, and Vancouver were selected for the main study based on Grosvenor's 2014 research thesis findings. Another reason for selecting these cities is the fact that the author is a Canadian and, hence, has better access to information in Canada. Also, getting in touch with different cities' representatives to try and interview them is difficult due to contemporary security concerns; thus, including only Canadian cities in the research was practical.

3.4.2. Step 2 – Questionnaire Development

The second step was to develop a detailed questionnaire drawing on the findings of the literature review that would take into account all aspects of resilience in these cities, including such aspects as the technologies being currently used, the technologies desired to be used, implications of using technologies, and the current problems cities are facing. The questionnaire consisted of nineteen open-ended questions where the respondent had full liberty in expressing their thoughts on the subject (Kotler & Armstrong, 2012). The goal of the questionnaire was to explore what cities' representatives think about the resilience of their city and how it could be improved if at all.

To achieve the goal of the study and to satisfy the objectives of the study, several types of information were necessary. Bloomberg & Volpe (2008) state that there are four possible types of information that can be gathered in a qualitative research study, including contextual, perceptual, demographic, and theoretical types of information. *Contextual* information describes the environment in which the research subjects live or work. This kind of information plays a supporting role in setting the stage for further research and analysis and is the most useful when studying human objects. *Perceptual* information is about the study subjects' perceptions. The best way to gather this information is through interviews. This type of information is considered to be biased by the respondents and should be used as a story-telling type of information rather than actual facts. *Demographic* information refers to socio-demographic information gathered about human objects, the participants of a study. This information encompasses such data as gender, age, ethnicity, education, occupation, etc. *Theoretical* information refers to a literature review using published sources. The objectives of gathering theoretical information are to explain the choice of methodology for a study, to provide conceptual support to the study, as well as to back up the analysis and/or conclusions and recommendations (Bloomberg & Volpe, 2008). For the purpose of this study, theoretical, perceptual, and contextual types of information were gathered using qualitative questionnaires.

The pilot questionnaire was designed as an open-ended questionnaire with the goal of collecting information from the pilot subject about the types of technologies they use for resilience, what they are looking to add, and what can be improved, if anything. A full copy of the developed questionnaire can be seen in Table B, Appendix 1***.*** In total nineteen open-ended questions were developed to allow the respondents to express their ideas freely and give as much information, perceptions, and opinions as possible. The questions were grouped as follows:

- Information-gathering questions: Questions 1, 3, 6, 7, 9, 11. The types of technologies and particular applications that the city uses.
- Insight-generating questions: Questions 4, 5, 8, 12, 13, 16, 18. How the city is using technology to achieve its resilience strategy goals.
- Future planning questions: Questions 2, 10. What technologies are desirable and how these will be used if/once deployed.
- Resilience checklist questions: Questions 13, 14, 15, 17, 19. How much the city agrees or disagrees with what it means to be resilient.

The order of the questions in the questionnaire is random to ensure that the respondent feels at ease when answering each question rather than being "interrogated." The advantage of such an approach is the fact that the respondent is more prone to providing more information and to answering each question fully. Answers that are equivalent to the full study questionnaire answers are presented in Table A, Appendix 1.

3.4.3. Step 3 – Pilot Study

Using the developed questionnaire, the third step of the study was to conduct a pilot study. The questionnaire was emailed to the representative of the city of Mississauga, and the representative was given sufficient time to respond to the questionnaire and provide feedback on the structure of the questionnaire instrument.

The city of Mississauga was chosen to conduct the pilot study. Mississauga is not only the city of residence of the author but also is one of the major Canadian and North American business and logistical hubs. Mississauga is also known in Canada for its resilience.

3.4.4. Step 4 – Final Questionnaire

Based on the feedback from the pilot questionnaire, the fourth step was to prepare a final questionnaire for the three subject cities of the study, the cities of Toronto, Calgary, and Vancouver. The final questionnaire consisted of twelve open-ended questions. The goal of the questionnaire was to learn about the current resilience practices of each city and what can be improved, if anything.

The final questionnaire was developed using the pilot questionnaire. With the feedback obtained from the pilot study, it became clear that the questionnaire was too long, and to increase the chances of respondents answering all the questions in the questionnaire, the number of questions had to be reduced. The new questionnaire consists of twelve open-ended questions. The majority of the questions from the pilot questionnaire were kept in the new version, and the questions were streamlined to guide the response of each participant. A separate question on 3D technology was added to the questionnaire based on feedback from the Pilot Study. Several questions that were somewhat repetitive were excluded from this version of the questionnaire.

The final questionnaire used in the study is presented below:

1. What innovative city applications of technology do you use? Could you elaborate why you use these technology applications?
2. Do you think that you lack any technological solutions to support city management?
3. Does your city try to use technology to increase citizen engagement? If yes, how does it and which technology is used?
4. How does your city leverage technology to improve operational efficiency?
5. What new technologies is your city using in supporting management of its infrastructure? Please list these technologies.
6. Please tick software tools that are currently used within your organisation for city management? Please specify.
7. Are you considering implementing alternative or additional software tools in the future?
8. If you had the ability to create a piece of software that had any functionality you require what might it look like? Why would these functions be useful?
9. Do you agree that 3D modeling of the urban environment can support urban resilience planning?
10. Do you agree that "smart cities" are the way of the future?

- If yes, please list your reasons.

- If no, please list your reasons.

11. Do you think that once a city integrates smart technology, the data will be out of your control?
12. Do you thing we voluntarily give up too much information about ourselves by using technology at the present time?

3.5. Phase 3 - Data Analysis

The data gathered using both pilot and final questionnaires were textual in nature. A two-step approach to analysing the data was taken. First the data were analysed using factor analysis to uncover best practices in resilience used by cities and what practices are repeated from city to city. Then, the data results were compared against published articles and other sources.

Factor analysis was used to analyse the data to be able to extract features of interest and compare them. Factor analysis is defined as "a method for investigating whether a number of variables of interest Y1, Y2, ..., Yi are linearly related to a smaller number of unobservable factors F1, F2, ..., Fk" (Tryfos, 1997). Factor analysis is used "to summarize data so that relationships and patterns can be easily interpreted and understood" (Young & Pearce, 2013).

For the purposes of this study, factor analysis helps to single out similarities among the pilot and actual study data and to be enable a comparison against published literature to further conclude what practices are scientifically recognized and what practices are new to resilience.

3.6. Ethics of the Research

There were no significant ethics issues when planning and conducting the research, as no vulnerable groups of people were affected or sensitive information shared during the research. The University of Wolverhampton's ethical procedure was followed and a copy of the submitted forms can be seen in the Appendix 2. The information provided by the cities' representatives is provided in accordance with the right of access to information by Canadian citizens and is hence of public domain. The cities' representatives were not asked to share confidential or any other kind of information or data that requires any type of clearance or is otherwise restricted. No non-disclosure or confidentiality agreement was signed and the purpose of gathering this information was explicitly stated upon the first contact with the cities' representatives.

3.7. Trustworthiness of the Research

Overall, the information gathered is credible as it is provided by credible sources, the cities' representatives. The information is dependable for the same reason, yet there is a possibility of it being influenced by the personal opinions of the representatives. The information is gathered by the author of this thesis and is non-transferable, as it is primarily and only gathered for the purpose of completing the current thesis.

3.8. Limitations of the Research

The main limitations of this study are related to the cities' cooperation, time and budget. The cooperation of the cities is the primary limitation, as it is a complex task to get cities to assign a representative to respond to a detailed questionnaire, provide the information required, and do so in a timely fashion. The other limitation is time, hence only one city was selected for a pilot study and only three cities were selected for the actual study - due to a time constraint regarding the collection and analysis of the data gathered. Ideally, the author would poll at least ten cities in Canada to include less resilient cities in the study and compare them against more resilient ones. Finally, budget is another constraint, as ideally the author would visit some of the cities and interview the representatives in person to gain a first-hand look into how resilience strategies work in the cities.

3.9. Summary

This chapter presented the overall research methodology employed within this study. Based on a 3-Phase overall approach, the research undertaken completed a state of the art review followed by a qualitative questionnaire approach for primary data collection. The findings of these methods were then analysed using factor analysis to develop a framework for resilience in Canadian cities.

A pilot study was undertaken of the primary data collection to test the questionnaire. This was followed by employing the refined questionnaire with 3 further cities namely Toronto, Calgary, and Vancouver. These cities were chosen because they are considered to be the most resilient cities in the world (Grosvenor, 2014).

The following chapter presents the results of the analysis and the discussion of the findings.

Chapter 4. Results and Analysis

4.1. Introduction

This chapter presents an analysis of the information gathered from the pilot study in the city of Mississauga, as well as from the cities of Toronto, Vancouver, and Calgary in the main research. The fact that the cities in question are considered to be some of the most resilient cities in the world (Schiller, 2014) and the fact that all of them are located in Canada were the main reasons for choosing these cities for this research. The representatives of these cities governments occupy managing positions or represent city planning functions within city planning departments. These people represent larger groups of people within the cities governments, hence they represent the official point of view of these cities governments on urban resilience.

The fact that this research is qualitative comprehends a relatively small number of participants. The purpose of this research is to create a framework that can be tested further rather than to test an existing framework, where a quantitative research would be pertinent and would require a relatively large number of respondents. To be able to create a framework, in-depth interviews with participants are required. In-depth interviews with cities representatives take a long time to compete due to geographical and respondents' availability restrictions. For the purpose of this study, it took 120 days to meet the participants, receive their agreement of participation, and to have them complete the questionnaires. It is important to take into account that there was no language barrier since all of the respondents were English-speaking, which facilitated the task of interviewing the representatives.

The reliability of the results of this study is demonstrated by the fact the results of the three interviews are similar to that of the pilot study, so it can be safely concluded that the results of the major study are representative and reliable within Canada. The fact that only three cities participated in the research was discussed with and approved by the thesis supervisor who also validated the results of the research are pertinent and reliable.

The following are the positions of the respondents in the cities governments:

<u>City of Mississauga</u>:	Manager of Information Planning Research and Intelligence Unit Planning and Building Department Policy Planning Division
<u>City of Toronto</u>:	Manager, Strategic Planning, Policy & Standards Information and Technology Department
<u>City of Vancouver</u>:	Graphics Planner Sustainability Group
<u>City of Calgary</u>:	Coordinator of Graphics, Modeling and GIS Planning, Development & Assessment

Two questionnaires were prepared to address the current research needs: the pilot questionnaire and the study questionnaire.

The pilot questionnaire is presented in Appendix 3 in full**.** The pilot questionnaire served several purposes: to do a test run of the questionnaire, to see how fully the city would respond to it, and to verify if and how an approach will be made to each city during the research to gather the necessary information about the cities' resilience strategies. The pilot questionnaire proved to be useful for the purposes it was designed to fulfill; it showed that the questionnaire was too long and that the best way to gather the required information from the cities was through one representative of each city. Mississauga was chosen as the pilot city for two reasons: Mississauga is the researcher's home city and it is also one of the most prominent cities in Canada, both economically and in terms of resilience. For these two reasons, Mississauga was an excellent place to work with when choosing a pilot city for the study.

The research questionnaire took into account the experience of the pilot questionnaire. The study questionnaire is shorter, yet it preserves the great majority of the questions from the pilot questionnaire and adds a few new questions. The questionnaire is presented in full in Appendix 4. The study questionnaire proved to be a success with the cities of Toronto and Vancouver, who gave very detailed responses to each question. The city of Calgary provided a briefer response, partially due to a recent climatic catastrophe that hit the city two years ago. Still, Calgary's contribution to the research is valuable and is included in the analysis presented in this chapter. The full questionnaire questions are listed in the Methodology section of this thesis.

4.2. Analysis Approach

The goal of the current research is to uncover and present best practices in urban resilience planning. To attain this goal, a study of four major cities in Canada is made. These cities are selected on the basis of their capacity for resilience, for which they are famous around the world. To attain this goal, the four major objectives of this study are a review of existing technologies in resilience, a pilot study of the city of Mississauga, a study of three cities, Toronto, Calgary, and Vancouver, and a conclusion from the above, which is a guide into resilience implementation that can be used in other cities around the world.

To be able to attain the objectives of this research, an inductive approach to the study is used. An inductive approach is characterized by the absence of a hypothesis at the beginning of the study. Such an approach is usually applied to qualitative data, deeper exploration of data and greater flexibility in adapting the methodology as the research advances (Saunders *et al*, 2007). Taking into account the fact that the research started with no hypothesis and that a large amount of qualitative data were gathered from four respondents using two questionnaires, deep exploration of the data is required.

The data gathered are textual information that requires manual processing and pattern definition to uncover best practices in resilience that are repeated from city to city. It is also important to note the differences and unique approaches to resilience that different cities use in their day-to-day work. Once these data are analysed for similarities and differences, a comparison to previous research described in the literature review shall be done to find links between the current research and previous research. This step also demonstrates an academic contribution to the area of study.

4.3. Actual Study: The Cities of Toronto, Calgary, and Vancouver vs. the Pilot Study in the City of Mississauga

Following the pilot study in the city of Mississauga, a new questionnaire was designed. This questionnaire was sent out to representatives of the cities of Toronto, Calgary, and Vancouver. The representatives of the cities of Toronto and Vancouver responded to the questionnaire fully; whereas, the representative of Calgary provided only a general response to the questionnaire without answering each question. A side by side comparison of the responses to each question is presented in this section.

A side by side comparison in this section reveals the similarities and the differences between the answers that each city representative gave to the questions in their respective questionnaires. Table 4.1 below shows the number of questions answered per city. For the purposes of this comparison, the pilot questionnaire sent out to the Mississauga representative was cut down to 12 questions to make it comparable with the rest of the questionnaires. It appears that the representatives answered between 10 and 12 questions out of the 12 that were posed. As mentioned earlier, the representative of the city of Calgary did not answer the questionnaire fully.

CITY	No of questions asked	No of questions responded	Percentage of questionnaire completed
Vancouver	12	11	92%
Toronto	12	12	100%
Calgary	12	2	17%

Table 4.1. The Number of Questions Answered by the Cities' Representatives of the Cities of Toronto, Calgary, and Vancouver.

4.3.1. Applications of Technology in the City

Since all of the cities involved in the questionnaire are located in Canada, it should not be a surprise that the applications and the software used in different cities are the same.

Some of the programs listed are common for all the cities. The uniqueness is in the availability of the resources offered to citizens at a local level. For example, Vancouver uses digital programs, while Toronto offers interactive online tools. Mississauga relies on tools open to the public, and Calgary offers its citizens a visit to City Hall to get the information needed. Overall, each city is doing its best to engage its citizens in one- or two-way conversations and to keep them informed.

Toronto and Mississauga list a large number of applications that they are using for resilience, and both cities use open data. Toronto is more focused on providing citizens with city services, such as public libraries and benefits cards; means of communication with the city, such as the 311 phone line; and sources of information, such as the city's website. Mississauga is focused on a two-way communication channel with citizens, such as social media; and city services in the form of the traffic network. Calgary is another city that mentions the use of many applications, yet the city representative did not list any of them. Vancouver makes use of few applications, yet, similar to other cities, it is also focused on engaging citizens in resilience through “engagement programs.” It is unclear whether Vancouver and Calgary make use of open data, but it can be inferred that they might be using it or considering using it.

Vancouver	Toronto	Mississauga	Calgary
MetroQuest	850 applications	GIS	
PlaceSpeak	City Services Benefits Card	Open Data	
Engagement programs	311 phone	Infographics	In the broadest sense
	3-D printing	Automatic	the City is making use of
	Toronto Public Libraries	vehicle locating	so many technological
	City’s Open Data program	Integrated	channels to help
	Online mapping	Traffic Network	improve citizen
	Waterfront Toronto	Social Media	engagement, create
	City building	Engagement	operational efficiencies
	City website	Platform	and help our leadership
	3-D modelling and mapping	Energy + green	make the best decisions
	Pictometry oblique imagery	technology	possible. Innovation is
	Big Data solutions		part of every business
	Business Intelligence		channel

Table 4.2. Summary of the Applications Used per City in Question 1.

4.3.2. Acceptance of Technology Innovations

The questions are related to the acceptance of lack of technology or the perception on how to manage access, security and the implications of making data available to the public.

Lack of Technological Solutions

A question was asked of each of the respondents requesting them to identify any technological solutions that they could use to improve management of the city and, therefore, enhance resilience.

The personnel polled think that they lack the tools to fully perform their analyses as presented in Table 4.3.

Vancouver	Toronto	Mississauga	Calgary
No particular tools, rather lack of information	Geo-social media	Information systems including map based Emergency Operation Centre (EOC) and more flexible Enterprise GIS.	N/A
	Unmanned Aerial Vehicles (UAV)	Alternative sources of information or alternative information sharing channels such as blogs.	
	Social Media		

Table 4.3. The Cities' Representatives' Answers to Question 2.

Toronto and Mississauga are pretty clear on the tools they are missing to support city management, whereas Vancouver points out that they are not lacking tools but rather information. Toronto and Mississauga both mention social media as a tool that they want to leverage further to get contemporary information, whereas Vancouver is missing historical information and data. There is no information on what technologies Calgary is missing to fully perform its job, if any technology at all.

Utopian Software Functionality for City Management and Resilience

Each respondent was asked to give their views on what functionality an idealistic piece of software might contain. This would include what functions would be available.

The people contacted appear to lack technical knowledge and are willing to have software that proposes ready-made solutions as demonstrated in Table 4.3.

Vancouver	Toronto	Mississauga	Calgary
"A tool to help visually simplify complex issues and to accurately convey the implications of the ripples of specific decisions across the city."	"Digital citizen and digital worker" Mobile Big Data Cloud Computing Social Media	Enterprise GIS	N/A

Table 4.4. The Cities' Representatives' Answers to Question 8.

The cities are looking for a digital ready-made solution to every problem or issue their city is experiencing or encountering. While Toronto and Vancouver focused on simplicity and digitalization, Mississauga sees a solution in an enterprise-like approach.

3D Modeling for Urban Resilience Planning

The people polled think that 3D modeling is important for totally effective resilience planning. The Toronto representative states that 3D modeling is still under-exploited, whereas in Vancouver, 3D modeling is widely used.

Transition of the Cities into "Smart Cities"

The representatives believe in a new way to construct cities and are optimistic regarding smart cities. Toronto and Mississauga see “smart cities” as a way to improve citizens’ lives. Vancouver sees this as a way of natural progress for the city.

Databanks with Smart Technology

The people polled believe that their data are secured at 33%, but they are unsure at 67% as seen in Table 4.6. This perception may be due to insufficient knowledge of licensing and legal terms. Vancouver and Toronto are dubious about how citizens’ privacy will be affected by smart technology integration. Vancouver sees a solution in engaging citizens in the process of smart technology integration, whereas Toronto’s representative suggests further research into this area. Mississauga’s representative believes there are no problems associated with smart technology integration.

Personal Information Disclosure

The cities’ representatives think that our privacy and identities are at no risk at 67% but they are unsure at 33%. Toronto and Vancouver are dubious in their answers, whereas Mississauga’s representative agrees and states that personal information disclosure happens in hopes for a better future.

4.3.3. Future Technologies

The answers to questions 5, 6 and 7 are summarized in Table 4.5. The cities' representatives specify the current technologies and the future technologies that will be implemented in the analysis of data. However, the cities' representatives mentioned that the future technologies are in fact already in use, but at the training stage. These questions showed that geographical systems are the most important and are used by the cities. This should not be a surprise, since most of the universities and government institutions use geographic licensed software as well.

Vancouver	Toronto	Mississauga	Calgary
Autodesk InfraWorks	ArcGIS	ESRI ArcGIS	ESRI ArcGIS
MapInfo Pro	ArcGIS online	B.I. technologies	CityEngine
SketchUp	SketchUp	SAP analytics	Sharepoint
Autodesk Map 3D	Windows/Unix/Apple	spatial analyst	Custom web applications
ESRI ArcMap	Mobile Device Management	Network analyst	Peoplesoft
HAZUS, LiDAR	SCADA	3D analyst	POSSE
Synthicity / Pictometry	In-house tracking	CityEngine	Adobe CS

Table 4.5. Summary of the Technologies Used by Each City, According to Questions 5, 6, and 7.

All four Cities use ESRI ArcGIS with the exception of Vancouver, which only uses ArcMap. Since ESRI ArcGIS is the most popular Geographic Information System, it can be expected that most cities are using it. Toronto and Vancouver also use SketchUp software. Vancouver uses several mapping applications, such as ManInfo Pro and Autodesk Map 3D as well as ESRI ArcMap. Mississauga is the only city to use the SAP system, whereas Calgary is the only one to use Peoplesoft.

In the particular case of future technologies, the cities established that they need specialized new techniques such as LiDAR in Vancouver or more modules of ESRI. In Toronto, the person seems to have perceived that the question is asking which technologies are still under development and need improvement, so the list of technologies covers several programs in the city.

Vancouver	Toronto	Mississauga	Calgary
LiDAR	Identity Management Enterprise Collaboration Platform Social Media Management Client Relationship Management Online Booking Scheduling Management Enterprise Application Integration Enterprise Service Bus GIS Management and Mapping Enterprise Business Intelligence Platform Electronic Forms Master Data Management Mobile Computing Management Payment Portal (public, employee) Notification and Distribution Wireless Network Mobile, Cloud Computing Big Data, Social Media	Several modules of ESRI	N/A

Table 4.6. Future Technologies from Question 7.

4.3.4. Comparative Analysis of Questionnaire Responses with Literature

In the sections above, the technologies being used or planned to be used or dreamed of are discussed as per the information received from the cities of Mississauga, Toronto, Calgary, and Vancouver. Whether the cities made their decisions to use one or another technology based on scholarly research and/or advice is not clear at this point, it is still possible to find scientific support for each of these choices. In the paragraphs below, a comparison of insights generated by the research is made against scholarly articles where these technologies are discussed.

3D Modeling

3D modeling for city planning was mentioned several times during the research: Vancouver uses 3D modeling for city planning, Toronto is planning to use 3D modeling and states it is under-exploited, Mississauga sees it as a solution for many of the planning issues the city has. Kemec *et al.* (2015) explore the importance of an enhanced 3D modeling to predict the outcome of a natural catastrophe that may unleash on a city. The authors propose to take a deeper look at what happens to a city's infrastructure not only outside but also on the inside in case of a mudslide, flood or another natural disaster (Kemec *et al.*, 2015; Kolbe *et al.*, 2011). The authors further note that a development of three-dimensional data gathering and processing techniques is required (Kemec *et al.*, 2015). The latter agrees with what Toronto's representative states about 3D being under-utilized due to the lack of technology for data gathering and processing.

3D modeling of a city involves more than a representation of a city on a screen of a computer. Other information, such as the number of floors in each building, where each entrance and exit of a building is located, what windows in the building have visual access to a certain place, and the "total area of seated surface" should be included (Kolbe, 2009). To tackle each of these issues the so-called “Semantic 3D modeling” comes into play (Kolbe, 2009). Semantic 3D modeling serves four purposes: to evaluate a city’s needs for electric energy, to create a geographic three-dimensional representation of a city, to efficiently manage the physical space of a city, and to manage and map pollution by noise in a city (Kolbe, 2009). Mississauga, Toronto, Calgary, and Vancouver mention that they are using 3D modeling or are planning to enhance its usage to plan city services, such as waste management, transportation, construction and soil use planning, such as parks and recreation zones, as well as for festivities and other activities in the cities. These types of planning activities are in line with Semantic 3D modeling even though none of the cities’ representatives points to the Semantic part of three-dimensional modeling.

Social Media

All four cities’ representatives mention social media as a source of information for the cities or as a means of communication with the general public. Even though none of the cities’ representatives mentions social media as a source of information on the general mood of the public in the cities at any given time, it can be inferred that the cities use this information to predict any potential unrest that may happen in the cities during large gatherings or events. Hudson-Smith (2014) states that through “mining social networks for key words and applying sentiment analysis, linked to location… it is possible to gauge the mood of a city and to predict where and when future unrest could occur.”

Resilience Planning

Vancouver is the only city of the four cities polled where a representative talked about using historical data for resilience planning. The representative of the city of Vancouver points out that there is lack of contemporary data on the types of buildings in the city and the condition of their ground floors, which prevents the city from proper resilience planning. Vermuru (2008) points out that resilience planning directly depends not only on having the information on a city's infrastructure in hand but also on the topology of a city. He further explores the notion with the modeling of a number of natural disaster events that provoke a cascade of disruptions in a city's infrastructure and elsewhere. He concludes that a city's resilience cannot be ensured solely by knowing and adapting its infrastructure. A city requires "a combination of redundant topology, increased flow carrying capacity, and other non-conventional consequence reduction strategies, such as layout homogenization and the deliberate inclusion of weak links for network islanding" (Vermuru, 2008). He further concludes that a more systematic approach to resilience can make a significant difference for a city (Vermuru, 2008). Hence in the case of Vancouver, it is not only the infrastructure information that the city is missing but also the whole systematic approach to resilience that the city may or may not have in place. In the latter case, the city should be solving a more strategic problem of resilience planning instead of resolving a more tactical problem of a potential flood in the city.

Geographic Information Systems and Building Management Information

All four cities are using ESRI ArcGIS in one or another way for their city planning needs, yet, as mentioned before, city planning requires not only external planning but also an internal component. The internal component is briefly mentioned by Vancouver, where the city representative points out that information is missing to be able to plan for floods in the city. Scholars are looking into adding another layer of information into conventional GIS to make it suitable for planning of both external and internal parts of a city. Van Berlo and De Laar (2011) discuss the addition of the so-called "Building Information Modelserver," an open source module, to the already existing GIS. The authors note that even though such a module is currently under development, a physical possibility of such integration exists and will address the Semantic design needs of a city (Van Berlo & De Laar, 2011). Such innovation would address Vancouver's designing needs as well as those of the other cities in this research.

Big Data

Toronto's and Mississauga's representatives mentioned that they were using big data for city planning purposes. Usually such applications are targeted at predicting how a city's existing infrastructure needs to be adapted to meet a growing demand for its services from a growing population. Defining a breaking point is also one of the objectives. To test the validity of such an approach, archaeologists from the University of Colorado in the USA applied it to ancient Mexican cities. The results of their research correctly demonstrated the time and the population at the peak of development of the major Mexican cities during the Aztec era, from 1500 B.C. to 1500 A.D. (Archaeological Institute of America, 2015). It is safe to state that using big data to predict a city's lifespan and to prepare a city for the next step in its development is the correct way to approach the problem.

Regardless of its usefulness, big data raises many concerns when it comes to gathering, using and sharing these data. In cities, a lot of data are generated both directly and indirectly by inhabitants of a city. Oftentimes, inhabitants are unaware of their private data being collected despite the fact that most of the time disclaimers are clearly presented everywhere when such data are collected. Such data are used by city authorities for decision-making, planning, and forecasting of current and future needs. Despite this altruistic cause, there are still concerns about the privacy and security of such data and, ultimately, of the people who produce such data. The representatives of all four cities voiced their understanding and, sometimes, concerns about this. In some cases, such concerns are understood as the price of progress, in other cases, these concerns are a matter open for discussion. Pflugfelder (2015) states that even though big data is a part of scientific progress, privacy issues should not be left unaddressed, and populations should be educated as to how, when, and why they share their data. The author further underlines the importance of proper data management and use by those who have access to it (Pflugfelder, 2015).

Other Technologies Overview

Pena-Mora *et al.* (2008) discuss the technologies designed for resilience. These technologies are divided into three categories: "preparedness against (i.e., before disaster), response (i.e. during disaster) and recovery (i.e., after disasters)". These are listed below:

- "Radio Frequency Identification (RFID) based techniques for structural assessment…" (Pena Mora *et al.*, 2008) discussed in section 2.5.2. in Chapter 2 of the thesis;
- "…a Segway-based information provisioning platform for field-responder's mobility and disaster site data collection…" (Pena Mora *et al.*, 2008) discussed in sections 2.5.2. and 2.5.8. in Chapter 2 of the thesis;
- "…Geospatial Information System (GIS) for optimal resource optimization…" (Pena Mora *et al.*, 2008) discussed in section 2.5.1. of Chapter 2 of the thesis;
- "…Computer Vision and Image Processing technologies for scene reconstruction using real-time visual data (images and/or video stream) from disaster site…" (Pena Mora *et al.*, 2008) discussed in sections 2.5.4. and 2.5.7. of Chapter 2 of the thesis;
- "…Augmented Reality technology for visualization of disaster damages and accessibility to various locations…" (Pena Mora *et al.*, 2008) discussed in section 2.5.6. of Chapter 2 of the thesis;
- "…application of Building Information Modelling for knowledge extraction for pre-disaster status and also as a baseline for visualization of structural discrepancies as well as building black-boxes for in-building

data storage” (Pena Mora *et al.*, 2008) discussed in section 2.5.5. of Chapter 2 of the thesis.

It is important to note that some or most of these technologies are being used by the cities of Mississauga, Toronto, Calgary, and Vancouver for resilience, as these cities are in line with the most contemporary research in the area of urban resilience. Pena-Mora et al. (2008) support the cities’ idea of combining technologies to improve resilience.

Other software packages available specifically deal with resilience planning. Geo-Adaptive is not being used by any of the cities in the research; however, this is a powerful tool that allows for planning, monitoring, and comparison with other cities’ resilience effort. It also highlights potential solutions to present and future issues (Geo-Adaptive, 2015a, b).

Resilience of Cities’ Infrastructure

Vancouver’s representative states that the city is lacking information on the condition of buildings in the city and their ground floors. The representative further elaborates that the city is in need of this information to develop resilience strategies in case of a flood. Along the same lines, Chang *et al.* (2013) developed a new approach to urban resilience and tested it on the example of Vancouver. The authors’ findings confirmed the city representative’s opinion that it is necessary to develop a new resilience strategy for the city, in case of an earthquake and subsequent flood. The authors suggest that it is “incomplete incentives, partial information, and few opportunities for learning” that create the major vulnerabilities. Hence, they suggest that “(i)nformation sharing, iteration, and learning among the participants” will ensure better preparedness and a better resilience strategy in case of natural disasters (Chang *et al.*, 2013).

Nexus Resilience

Apart from buildings being potentially damaged by a natural disaster, each catastrophe brings along a destruction of other physical and non-tangible systems in cities. These are divided into two groups and include the following (The Next Practice Ltd., 2015):

- “Risks to public health and safety”, among them:
    - “Health crisis / social vulnerability
    - Public safety
    - Food shortage
    - Loss of critical refrigerated medicines
    - Evacuation of buildings
    - Hospitals to capacity
    - Public disorder, crime increases
    - Smog conditions
    - Inadequate emergency response capabilities
    - Most vulnerable people at highest risk”
- “Risks to buildings and infrastructure”, among them:
    - “Power supply loss
    - Water supply loss
    - Road damage
    - Landscape damage

- Loss of communication
- Risk of fire
- Ecological damage: trees / parks / landscape
- Damage to existing buildings”

Having alternative ways to temporarily replace each of these functions in cities determines the resilience of a city. Such solutions encompass a large number of measures, including, but not limited to, setting up mobile healthcare units, scientific research into the most vulnerable geographic areas, ensuring information-sharing channels are always available in case of an emergency, setting up and maintaining in good order food banks and water pumping stations, etc. (The Next Practice Ltd., 2015).

Economic Resilience of Cities

The representative of Toronto discussed the approximately 850 software applications that the city has in place for its inhabitants. Some of these applications are directly related to urban disaster resilience, such as GIS, Business Intelligence, etc. Other applications and services are in place to provide relief and assistance to those citizens who are most vulnerable economically and otherwise. Such services include social assistance using City Services Benefits Cards, public libraries that offer access to the Internet, textbooks and other books, journals and other learning materials, as well as meeting rooms at no charge. Rosenzweig *et al.* (2011) discuss resilience from the point of view of assisting economically-vulnerable citizens to ensure that overall cities grow strong not only in terms of infrastructure but also in terms of their citizens' well-being. Rosenzweig *et al.* (2011) suggest that urban resilience must be focused on contributing to poverty level reduction as well as reduction in the vulnerability of its citizens. The research suggests that such factors as "urban climate hazards, sensitivity, adaptive capacity ... interactive consideration of mitigation and adaptation in critical urban sectors – energy, water, transportation, and human health – and the inclusion of overarching integrating mechanisms of urban land use and governance" can become game changers when it comes to planning urban resilience in economic terms.

4.4. Framework Development

The section below is based on the insights generated from the literature review presented in Chapter 2 of the thesis and own research presented in the Chapter 4 of the thesis so far. Furthermore, from the analysis of the questionnaire, and taking into account the comparison with existing research and literature in the field of resilience, several key themes emerge with respect to developing a framework for guidance to cities on urban resilience. In particular, the following themes appear from the literature review analysis and data gathered and analyzed by the author:

- Training
- Software
- Security
- Big Data
- Cost

4.4.1 Training

The first group of recommendations concern personnel training. Be it in a city, in government, or in a company, personnel training is vital to understanding what resilience is, what instruments allow people to build and maintain it, and how to use those instruments effectively to achieve the desired benefits. The training group of solutions includes:

- The definition of resilience in order for those involved to understand what resilience is and how it is different from sustainability and other concepts;
- Development of an audit tool to evaluate how resilient a city/government/company is. The tool is scalable and can be used for any application in any city, town, government, or company worldwide; and
- A focused national training program developed to satisfy the needs of a city and tackle the weak spots in knowledge and skill sets.

4.4.2. Software Systems

The second group of recommendations concerns software and systems used for resilience in a given city, by a given government, or by a given company. It also refers to what the subjects have on hand and what they do not have but need to acquire. This group of solutions consists of the following elements:

- Open-source software as a replacement for expensive licensed software and, in some cases, as a solution to not having any software in place at all;

- Automation of data processing as a solution to having piles of untouched, and, thus, useless and aging, data that could be used to support decision-making in a city or other levels of government or for company management; and
- User-friendliness, which is important when using software and systems that personnel are not familiar with but are required to use to produce valuable output. User-friendliness defines whether city or government or company personnel can supply their supervisors with information/analyses/insights necessary for decision-making or whether decisions have to be made without such support.

4.4.3. Security

The third group of solutions is security. Security refers to how secure a city, government, or company's systems are and how vulnerable a city, government, or a company can be to outside attacks. This group of solutions includes the following elements:

- Security clearances, which are about maintaining full control of sensitive information within a city, government, or a company;
- Data encryption, which ensures a fully-secured data exchange when/if such data need to be shared electronically; and
- Data security management, which encompasses a range of measures that are put in place to prevent and apprehend any un-authorized access, manipulation, distribution of sensitive data within a city, government, or a company.

4.4.4. Big Data

The fourth group of solutions is about Big Data. Big Data is used by cities, governments, and companies for the creation of resilience strategies. The solutions recommended are as follows:

- Social media analysis refers to Big Data gathered from social media. Such examples of useful data are thesiss on a city infrastructure at risk of failing, etc.;
- GPS-based analysis is becoming more popular year after year as more applications are developed around GPS information and data, including anything from a handheld GPS to satellite-based applications; and
- Interdepartmental database integration is about sharing data between departments in a city, government, or a company that rarely share the data outside of their respective departments.

4.4.5. Cost

The fifth group of solutions is about the cost of acquisition of software, systems, and other costs. The elements of this group include the following solutions:

- Funding and grants for training refer to federal or provincial government financing for cities, other levels of government, and companies to educate about resilience, train and promote the creation of resilience strategies;
- Budget contributions, from municipal and federal governments, are about reserving a part of budgets at each level of government for resilience education, training, and implementation; and

- Free open-source software and systems is a solution to saving the funds necessary for resilience strategy execution instead of spending it on expensive software and systems.

4.4.6 Framework

Based on the foregoing, it can be seen that each of the areas is a ‘building block’ for the development of a resilient city. However, as seen in the results of the questionnaire, and also from the information obtained from the literature review, this is often not the case in Canadian cities at the present time. Figure 4.1 below provides a framework for cities in Canada, which can be further developed to create a toolkit for cities to analyse their resilience capabilities. Whilst this is outside the scope of this study, future research could use this framework as a basis for toolkit creation.

Resilient City Framework

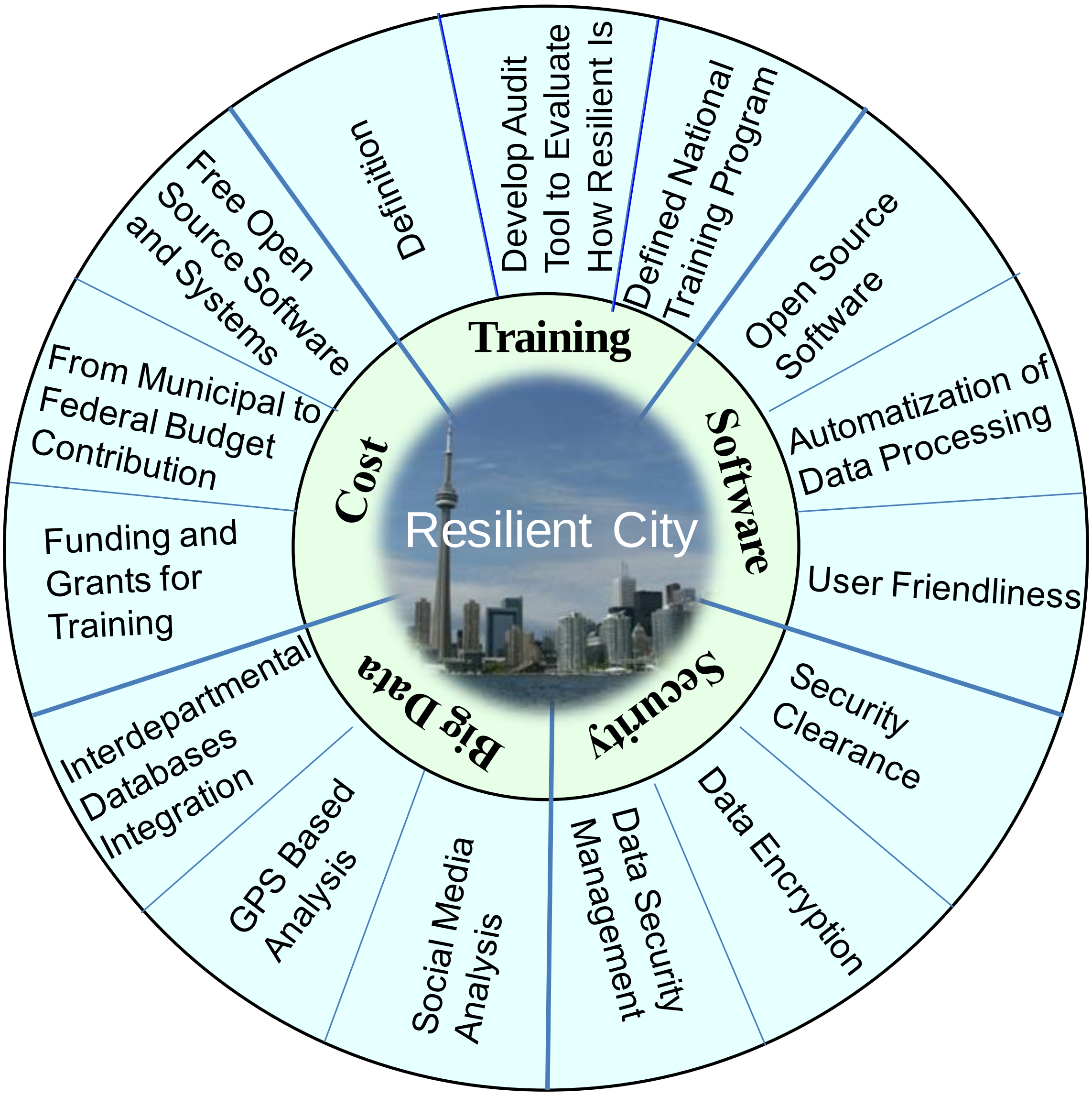

Figure 4.1. Resilient City Framework that Constitutes the Contribution of this Research.

4.5. Summary

This chapter presents the findings from the questionnaire survey undertaken to fulfill objectives 2 and 3 of this study. The results of the questionnaire survey highlight a range of similarities between the cities investigated. There are some similarities in terms of the software tools used by the cities for urban management; however, some seem to be further down the adoption and exploitation curve than others. All of the cities utilise geographic information systems to locate, forecast, and prepare projections of city resources as well as to manage natural and man-made disasters in the best possible way. Furthermore, with respect to resilience, there is a general lack of common understanding and also a lack of data to support resilience planning.

Based on the results of the literature survey and the questionnaire responses, a framework is presented based on five key elements that each city requires in order to move towards being resilient. Potential solutions are then developed for each of these key areas. This framework could further serve as the basis for the development of a resilience assessment toolkit for Canadian cities in future research.

Chapter 5. Conclusions and recommendations

5.1. Introduction

In this chapter, conclusions for the research presented in the previous chapters are presented. These conclusions encompass the research into the three cities and the pilot city and focus on what the cities share in common in terms of their needs towards improving their respective cities' resilience and solving their day-to-day issues. The recommendations present a scalable model for problem-detection and potential solutions that can be applied to virtually any city or town around the world. The recommendations presented are directed at practical and theoretical applications.

This chapter continues with a restatement of the aim and the objectives of the study to remind the reader about what achievements were planned at the beginning of the study. A critical assessment of the achievement of these is presented in the following section of this chapter, where a discussion of how each objective and the overall aim of the study were fulfilled and to what extent. The overall conclusion presents general points of similarity regarding the cities' resilience strategies with which the research concludes. The recommendations give an overview of the conclusions for the study, and the following two sections of recommendations directed at practical and theoretical applications discuss these recommendations in detail.

5.2. Study Aim and Objectives

The aim of this study was to provide a framework for guidance on the best practices for urban resilience planning. The study results are further supported by factor analysis, and the author’s reflections on the information and data gathered help define the instruments usefulness in resilience planning and execution. This research was conducted following the four objectives described in section 1.2.4. The first objective of the study was a presentation of a critical review of technologies used to support resilience. The second objective of the study was to conduct a pilot study to learn about the instruments used for resilience by one of the resilient cities in Canada. The third objective of the study was to conduct research in three resilient cities to ascertain what technologies they are currently using and are looking to acquire in the future, and how this use of technology is in line with current scientific thought. The fourth objective was to develop a framework that was scalable and can be applied in any city.

5.3. Overall Conclusion

Three key conclusions can be drawn from the work undertaken in this study relating to:

- Definition of resilience
- Resilience reaction speed
- Systems and software

It has become apparent, from this research study, that the cities' representatives confuse a sustainable city with a resilient city. In their responses to questions, the cities' representatives often would substitute resilience for sustainability and vice versa. Moreover, it seems that there is no clear understanding of what resilience means, as the cities' representatives would consider it to be the same as sustainability. Such confusion can be explained by the fact that sustainability and resilience are often used interchangeably or together to explain new phenomena both in industry and in government settings (Redman, 2014; GreenBiz, 2015; Climate Etc., 2013). While scholars call for separating the two concepts and researching each one of them separately and nourishing them (Redman, 2014), industry offers a new generation of "resilient investors" that depend greatly on the "sustainable global economy" thus creating a bridge between the two concepts to be used if not interchangeably then at least complementarily (GreenBiz, 2015). Other industry investigative journalists note that urban "green" building standards are mistakenly presented as urban resilience: "After 9/11, Lower Manhattan contained the largest collection of LEED-certified, green buildings in the world... The buildings were designed to generate lower environmental impacts, but not to respond to the impacts of the environment" (Climate Etc., 2013). This is a rather alarming finding of the research, taking into account that the cities' representatives are the ones who are supposed to build and maintain resilience in their respective cities.

A further conclusion surrounds the reaction of cities to major disasters and the speed in which their 'resilience' can return the city to its previous state. Despite the fact that there is a great variety of instruments that the cities are using to build and maintain resilience, their resistance level to major stresses, crises, and catastrophes, including floods, earthquakes, heat waves, and ice storms appears to be low. For example, Calgary suffered a major flood in mid-2013. The city's core was fully flooded and other areas of the city suffered significant damage as well. Two years later, the city estimated their damages to be worth several billion dollars, and the city is still struggling to rebuild their damaged infrastructure (Huffpost Alberta, 2015). Other cities in the study have suffered from nature-made crises, such as the ice storm in Toronto in late 2013, and the regular rain storms in Vancouver. In the case of the Toronto ice storm of 2013, the bounce back time was at most a week, yet it led to 2.3 billion dollars in losses in shipments delayed or cancelled (The Star, 2013). Despite the fact that some disasters require more time to bounce back than others, their financial impact is equally damaging. The financial impact alone demonstrates that despite the over three hundred systems and software that are being used in Toronto, and an equivalent in Calgary, to build and maintain resilience, the cities are still suffering serious consequences from each natural disaster. Those examples show how software and data are part of resilience planning, and why it is important to improve them constantly.

With respect to the types of system that every city is using for various resilience-related functions, it is noted from this study that every city, including the cities of Toronto, Calgary, and Vancouver, as well as the city of Mississauga use Geographic Information Systems (GIS). The system allows for performing a large variety of tasks, from the very simple to the most complex; thus, it is the preferred system for every city. GIS is a commercial system, much like the Windows operating system, but due to the fact that the number of users is relatively small compared to the number of users of, for example, Windows, the price of a licence is very high, even for governments of cities. Those cities that acquired the system at some point in the past rely on it until a newer version is needed. Those cities that do not yet use the system are looking to acquire it, and the high cost of a license is an obstacle for them. Another obstacle is the fact that data manipulation and the various modules or platforms of GIS are pretty complex, which raises the question of users training, which is both time-consuming and costly.

5.4. Recommendations for Cities

This section presents the recommendation of a general nature that are scalable enough to be applied to any city or town anywhere around the world where computer power and broadband communication power allow for gathering and processing vast amounts of digital data.

The first general recommendation is based on the research conducted and is targeted at solving the problem of using a licensed version of GIS that is both expensive and less user-friendly. An alternative solution to GIS is the Geographic Resources Analysis Support System or GRASS GIS (Neteler et al., 2012). It is an open-source and free alternative to the Geographic Information System or GIS. The main advantages of this system are:

- GRASS is available at no cost and it can be used by governments, companies, and individuals alike,
- GRASS is an open-source system, which means that every user can contribute to the code and improve it,

- The GRASS suite of modules is used for geospatial data management and analysis, image processing, generation of graphs and maps, spatial modeling, and visualization. All cities' representatives in the study mentioned they were using some or all of these functions,
- GRASS is used in academic and commercial settings worldwide, which demonstrates its adaptability to varying environments and makes it suitable for use in a government setting as well,
- GRASS is also used by government agencies and environmental consulting companies, which further demonstrates that the system is universal,
- GRASS is a founding member of the Open Source Geospatial Foundation or OSGeo devoted to "support the collaborative development of open source geospatial software, and promote its widespread use" (OSGeo, 2015); and
- GRASS offers free online training for its users.

As with any system, GRASS has its own peculiarities that need to be taken into account by those willing to adopt it. These peculiarities are:

- GRASS was designed for scientific purposes, which may make it somewhat less user-friendly for practical applications. A solution here would be to use QGIS, another open-source and freely available Geographic Information System designed for practical applications (QGIS.org, 2015),
- GRASS uses its own data format; hence, when the data need to be prepared for use in other applications, it needs to be imported or exported into another format. This difficulty can be offset by using the

SEXTANTE plugin provided and supported by GRASS. By using this plugin, data can be exchanged between GRASS and QGIS (Neteler et al., 2012), and

- GRASS is designed for scientific use and for complex applications. For simple mapping QGIS is more user-friendly and may be used instead of GRASS as needed (Neteler et al., 2012).

As seen above, the GRASS system can be used by any city anywhere around the world. The facts are that the system is free, open-source and provides all the necessary instruments for building and maintaining resilience. This makes it scalable and adaptable for any city's or town's needs. QGIS is another strong system that helps address issues similar to those addressed by GRASS, yet, it is more user-friendly to those users who are looking for simplicity in developing their solutions. There are as well the tools GRASSROOTS MAPPING (2015) and ESRI (2015) that are used and are equivalent to GRASS, and it is suggested to the interested reader to consult their references for a detailed description.

The second general recommendation concerns the confusion between sustainability and resilience. As described above, scholars call for distinction and further research into each one of these concepts, whereas the industry calls for the merging of them (Kim & Lim, 2016; Chelleri & Olazabal, 2012; O'Brien, 2012). There is a principal difference between the two concepts: sustainability is about the business-as-usual setting; whereas, resilience is about getting ready, getting through, and recovering after a crisis, major or lesser. The confusion between the two terms leads to cities' inability to prepare, deal with a crisis and its aftermath; as living in the business-as-usual setting does not call for preparing for a potential crisis. For cities to become and stay resilient, it is important to understand and act upon the difference between sustainability and resilience. Resilience should be very much a focus for every city and town around the globe in the twenty-first century. Climate change, political instability, impoverishment of large and densely-populated regions, rapid population growth, and the propagation of long-forgotten diseases are some of the factors that can make or break a city, should a potential natural catastrophe not be controlled and properly prepared for. This calls for the education of cities’ and towns’ personnel about resilience, its meaning, and most of all its importance to the very survival of a city, a town, and the people living there.

Modern societies are still very dependent on climatic conditions. In the present century, humanity is confronted with climate change from anthropogenic origins. The effects of such changes might affect food supply and the way cities work. This constitutes a debate between the sustainability of cities and resilience against climate chaos or climate volatility. The debate is whether, in years to come, cities will be more concerned with adapting to and mitigating climate changes or if cities will concentrate their efforts and resources in resilience from the impacts.

5.5. Recommendations for Future Research

The recommendations presented above are practical applications for cities, governments, and companies. The latter cannot be expected to research resilience further, as their primary function is to execute resilience, keep citizens safe and to reduce the impact of natural and man-made disasters. When it comes to research, these recommendations are directed at scholars.

The current research was focused on the large cities in Canada, so were the analyses, conclusions, and recommendations. Future research would benefit from looking into smaller cities and towns and the problems that are topical only to them. Some of the issues they are facing will be similar to those of large cities; this is where the current recommendations are scalable and are applicable to the smaller cities and towns. But some of the issues will be typical only of smaller towns, such as lack of financing from the federal/provincial government, the problem of outflow of population towards the larger cities, fewer jobs leading to higher unemployment and fewer taxes paid to the city, among other issues. It is important to identify these patterns not only at the national scale of one country, but also to look into other countries of a given region and to figure out whether, if at all, there are similarities among them. Findings of such research and the subsequent recommendations developed as a result of such research will be applicable to smaller cities and towns anywhere in the region. A similar study on a worldwide scale could be beneficial to many smaller cities and towns in the variety of conclusions that can be drawn and recommendations offered.

This research can be used as the basis for the development of a toolkit for cities which could help to evaluate how compliant cities are with resilience. This toolkit should be in agreement with the policies of the cities. As presented in Figure 4.1, it is possible to diagnose and to improve the training of workers. Figure 4.1

should be the backbone of the toolkit. It is very important that the toolkit be constructed in collaboration with each city. This will ensure that the toolkit is well adapted for the particular conditions of the city.

5.6. Summary

This chapter presents conclusions to the thesis and recommendations for cities in Canada as well as recommendations for future research. The chapter starts with an introduction to the problem thus refreshing the reader’s memory on what the topic is about and how the thesis represents a scientific contribution to the subject of urban resilience in Canada. The chapter concludes the research with restating the major findings and their importance to urban resilience in Canada. With this, the thesis denotes its scientific contribution to the topic and provokes the reader to think about urban resilience in Canada from the author’s point of view. The recommendations to the thesis are divided into two parts, the recommendations concerning urban areas in Canada and the recommendations concerning future research into the topic. These recommendations are designed for other scholars to take on the topic of urban resilience in Canada and continue their research further using the findings of the current thesis. It is the author’s sincere hope that the contribution of this thesis and the recommendations will serve as a basis for many other graduate-level research projects in the area.

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Appendix 1

Table A. Answers to the Questionnaires Presented to the Cities of Mississauga, Toronto, Vancouver, and Calgary.

No.	Vancouver	Toronto	Mississauga	Calgary
1	MetroQuest http://metroquest.com/ for public engagement. In the past we have also worked with PlaceSpeak https://www.placespeak.com/ For city modelling work we currently work with Autodesk InfraWorks. Vancouver has a history of successful public engagement programs, especially for planning related initiatives. Our traditional approaches were becoming difficult to sustain because of cost. As well, as the public becomes more proficient with design and analysis tools there is a need to change the approach.	The City has over 850 applications that it manages and delivers to support both online services to the public and the City's 2.8 million residents as well as internal business operations across 44 divisions. Some examples of innovative solutions include the City Services Benefits Card providing a reloadable debit card (as opposed to the previously used cheques) to Toronto residents requiring social assistance, 311 phone and online for non-emergency City services inquiry, 3-D printing and learning in Toronto Public Libraries, the City's Open Data program (over 190+ datasets published), online mapping for major capital infrastructure projects, the Waterfront Toronto revitalization embracing the digital citizen/workforce with broadband connectivity as a part of modern City building, as well as continued enhancements to the City website to address accessibility and mobility needs as well as expanded online services. Specific to 3-D modelling and mapping, the City is using Pictometry oblique imagery to offer an additional layer of information for City divisions. Using oblique imagery provides users with the ability to see objects on an off-nadir angle, allowing users to measure	GIS Open Data Infographics Automatic vehicle locating (AVL) Integrated Traffic Network Social Media Engagement Platform Energy + green technology	In the broadest sense the City is making use of so many technological channels to help improve citizen engagement, create operational efficiencies and help our leadership make the best decisions possible. Innovation is part of every business channel.

No.	Vancouver	Toronto	Mississauga	Calgary
		and visualize features in 3D. The City is investigating 3D change detection software to identifying locations of change to assist with the foundation mapping update program, and we are also looking to further leverage Big Data solutions/Business Intelligence to support City program services planning and delivery. Ultimately the City is moving forward to continue to embrace being a "Smart City," where we focus on Quality of Life and meeting the overall social, economic and environmental goals of Toronto. This involves looking and planning for solutions in areas such as water management, waste management, transportation, buildings, environmental, health, social and economic development, public safety, emergency preparedness and disaster response, and recreation and culture to highlight a few.		
2	I would suggest that the lack is less related to the availability and application of technology tools and more to gaps in the data we need to make informed decisions. As an example, we recently were trying to determine the impact flooding and earthquakes could have on the city. We discovered that key information such as primary building construction type, and the first storey height of buildings was not available. There is no quick technological solution that could provide us with this information.	The city has established a strategy and framework to focus key programs to drive business transformation supported through technology. A thesis and presentation on the City's IT Strategy are available here. This is focussed to meet City Programs and Services requirements across the corporation and include driving forward business solutions in these areas: Online Service Delivery Case Management Procurement & Supply Chain Management Work and Asset Management Transformation Project Management	Map based EOC More flexible enterprise GIS Web based technologies (e.g. blogs, etc.)	N / A

No.	Vancouver	Toronto	Mississauga	Calgary
		Time and Attendance and Payroll Transformation Finance Transformation Employee Productivity Human Resources Transformation Open Government Information Management and Business Intelligence IT Foundational Components Over 180 IT projects are a part of the Programs above planned out over a multi-year roadmap to move forward. Specific to the geospatial realm and mapping, some areas where we are looking to explore include geo-social media and Unmanned Aerial Vehicles (UAV). The use of social media is relatively common place, but using the associated geographical information is relatively unexplored. UAV are becoming more popular within the aerial photography industry. Their usage, abilities, and legal limitations need to be further explored.		
3	Yes, we have a public engagement coordinator who sets policy for Twitter, Facebook etc. We use YouTube on a regular basis. A recent example I was involved with was providing information on the impact of an oil spill. https://www.youtube.com/watch?v=AlF9FwEiJgw Engagement software (e.g. bang the table, metro quest)	The City uses various social media channels, including YouTube, Facebook, Twitter, and Linkedin for example and has a significant Open Government/Open Data initiative. The City's Open Data program has over 190 data sets across a wide variety of areas with details available at www.toronto.ca/open. The City is also implementing a Civic Engagement initiative (using SharePoint technology) that will allow for more collaboration and online	Social Media / video Engagement software (e.g. bang the table, metro quest) Open data will lead to apps that will facilitate the items you mention below. For example, smart phones are among the most empowering tools cities are leveraging to get citizens engaged. They let cities do so many things that increase resilience, such as: empowering inhabitants to thesis problems more easily,	N / A

No.	Vancouver	Toronto	Mississauga	Calgary
	Yes, MetroQuest, Placespeak, and even Survey Monkey. Open data will lead to apps that will facilitate these items you mention below. We have a very strong open data programme, and the City has partnered in hackathons to explore how this data can be used to create important applications. Visit data.vancouver.ca	consultation between government and citizens, enabling more participation in contributing comments, online surveys, sharing of ideas, notifications for public engagement opportunities and common workspaces and knowledge bases for staff/citizens to work together. City staff are also enabled with Smart Phones (more than 15,000 mobile devices), and the City's website and applications are mobile friendly. The City also released an API through our 311 several years ago to allow 3rd party software developers to build applications to allow citizens to thesis issues like potholes and graffiti via mobile device, and this was embraced through the SeeClixFix app for example. Examples of how might include: Social Media / video Engagement software (e.g. bang the table, metro quest) Open data will lead to apps that will facilitate these items you mention below.	making cities safer and more responsive; increasing the speed of communication between cities and citizens during major events like disasters; and fuelling people-powered local politics in neighbourhoods.	
4	N / A	As noted above, the City has several programs to drive business transformation, including realizing operational efficiencies. Some of the key programs would include a focus on employee productivity, work and asset management, case management, procurement and supply chain, time and attendance and payroll, and finance transformation. Efficiencies and value in terms of business outcomes, revenue, citizen and business experience, are also considered in addition to efficiencies.	For example, by integrating new technology like the Internet of things, new sensor development and deployment, and new ways to get essential data into the hands of decision makers. Many large business services are managed through business applications Infor MAX – planning and building applications / inspections Avolve – digital plans of submissions TES – traffic network management system	N / A

No.	Vancouver	Toronto	Mississauga	Calgary
		Specific to geospatial and mapping, the City's foundation mapping program utilizes high resolution aerial photography and digital stereo compilation to extract geographic features with high positional accuracy. The collected features are used by many City divisions, such as Engineering and Construction, City Planning, Parks, Forestry and Recreation, Transportation Services, and others as input sources into their planning and analysis; which includes construction projects, urban renewal, utility assessment, and traffic analysis. In general, the City is taking an approach to sharing of information (with an awareness of privacy, confidentiality and security requirements), common platforms and datasets, and leveraging and re-using technology components for common integrated solutions to drive forward operational efficiencies and more sustainable solutions as well.	SAP (financials / HR) Sharepoint ATG web content management system	
5	We've just started working with LiDAR. Some very minor explorations of VR	See the response to questions 1 and 3 for some examples that relate to the Geospatial/mapping area. In addition, the City uses ArcGIS, ArcGIS online and SketchUp. For overarching IT infrastructure management, the City manages 3 Data Centres and networks supporting a variety of environments including Windows, Unix, and Apple. The City also uses Mobile Device Management software to manage mobile devices. For overall management of core-infrastructure	Cities already have access to a lot of data, and over the past few years have been implementing new strategies to use it better. They often don't need to invest in finding new data, but rather in aggregating multiple streams of data in one place to do a multi-dimensional review that looks at how all those streams overlap and connect, in order to draw conclusions that pull from all of them.	N / A

No.	Vancouver	Toronto	Mississauga	Calgary
		like water and transportation, we use SCADA systems in these areas; as well as for the management of work-maintenance and major construction projects, we have an in-house project tracking portal solution and maintenance system. For example, the Toronto Maintenance Management System managed 442,000 requests for road maintenance in 2014, $269m in road repairs, $18m in salt/sanding, $2.3m in leaf/debris collection, and over 710 bridge inspections. The City's Project Tracking Portal (for major construction projects) managed over $810m in cash flow in 2014 for 4,800 projects and over 2000 associated contracts.		
6	Autodesk InfraWorks MapInfo Pro SketchUp Autodesk Map 3D (custom links to Hansen for asset management) ESRI ArcMap HAZUS (disaster mitigation) Synthicity (pilot project using Urban Canvas) Pictometry (oblique and ortho photos)	See response in 5 which highlights technologies at a summary level.	We use ESRI GIS to solve most complex analysis in planning and building. The IT Department is looking at B.I. technologies to unpack and understand Big Data. (e.g. SAP analytics)	ESRI ArcGIS CityEngine Sharepoint Custom web applications Peoplesoft POSSE Adobe CS
7	We expect LiDAR and related tools to play a larger and larger role for both data capture and analysis.	Yes – the City is continuing to look at effectively investing in different technologies to meet our needs. Foundationally, we are moving towards integrated solutions to support services to citizens and business capabilities across the City. Some of the core foundation technology elements we are focussed on include (some implemented, some	ESRI ArcGIS Several modules including spatial analyst Network analyst 3D analyst CityEngine	N / A

No.	Vancouver	Toronto	Mississauga	Calgary
		planned): - Identity Management (public, employee) - Enterprise Collaboration Platform, Social Media Management - Client Relationship Management Online Booking and Scheduling Management Enterprise Application Integration and Service Bus Geospatial Information Management and Mapping Service (GIS) Enterprise Business Intelligence Platform Electronic Forms Master Data Management Mobile Computing Management (Application Development and Management) Payment Portal (public, employee) Notification and Distribution Wireless Network We are also looking to continue to embrace key trends in Mobile, Cloud Computing, Big Data and Social Media.		
8	A tool to help visually simplify complex issues and to accurately convey the implications of the ripples of specific decisions across the city.	We don't have a specific piece of software; however, we are focussed on being aware of key foundational trends in technology, in particular embracing the digital citizen and digital worker, and trends in areas like Mobile, Big Data, Cloud Computing and Social Media. The other key priorities are around meeting the needs outlined in the programs noted in question 2.	N / A	N / A
9	Yes. This is the specific area I am most	Yes, we do. This assists in planning for	N / A	N / A

No.	Vancouver	Toronto	Mississauga	Calgary
	involved with. At the most basic level it can start to make abstract issues visually real to the public.	many programs, such as urban/city planning, parks/forestry, water, engineering/construction for example. The current limitations associated to 3D visualization and modelling make it difficult to undertake and implement a 3D modelling project at the scale of the City of Toronto, however we do use 3D modelling for specific projects, sites or smaller portions of the City.		
10	Yes. My personal opinion is that Vancouver becoming a smart city is inevitable. This does not necessarily mean adopting the IBM, Siemens flavour of smart city. A city can become smart incrementally as new tools and technology emerge. There is certainly a need to be able to quantify many of the City's activities. For example, Vancouver wants to be the greenest city in the world by 2020. How do we go about tracking our progress towards this goal.	Yes. we do, very much so. We have a working definition of Smart Cities that helps to articulate why: "A Smart City uses digital technologies or information and communication technologies (ICT) to enhance quality and performance of urban City services, to reduce costs, to improve customer service, transform citizen experiences and to drive effective citizen engagement, ultimately to realize outcomes of continued and improved quality of life." This image captures the framework for our overall IT strategy to fulfill Social, Economic and Environmental outcomes to ultimately achieve and maintain a strong and vibrant Quality of Life in the City. It also illustrates the Digital Infrastructure as a central part of the delivery of key City services and ultimately a component of a successful and Smart City.	Totally agree. Analogy: car companies spend millions of dollars on engine diagnosis computers and software. In my view a city is a highly complex engine. We need to do more to monitor this city in order to avoid problems. It also helps to better understand the complex interrelationships between the moving parts, and in doing so will help us to plan for a better future city. And this data and modelling should be interconnected between departments.	N / A
11	This is certainly an issue the City is concerned with. While there is much to make moving more of our applications to the cloud concerns about control and privacy are making this a very cautious	This would have to be studied. Moving forward in the context of Smart Cities and all the data/information associated, for example, with the Internet of Things, there will need to be analysis done to understand	No. There are laws in plan to protect us.	N / A

No.	Vancouver	Toronto	Mississauga	Calgary
	process. Cities will need to reconcile their more traditional role of being in control to one that is emerging in which they are more of an active partner.	and ensure that information management practices/considerations are reviewed and potentially policies/standards put in place, to ensure privacy/confidentiality/security as well as encourage openness and transparency.		
12	No. – this is very much my own opinion and not that of the City.	This is a subjective question which has no clear answer. Within the City of Toronto, we encourage opening up government and open data, for example, within the context of protecting privacy and confidentiality accordingly. We also have an established information management framework with supporting policies and standards to help guide information management practices at the City, as we move forward on solutions and into the continued evolving realm of Smart City opportunities.	In some ways yes, but it is the cost of a better future. Recently I bought a car that has a black box (tracks me very much like a jet airliner). This tracking is the cost of finding out what happened during an accident with the spirit of preventing future accidents.	N / A

Table B. Answers to the Pilot Questionnaire Presented to the City of Mississauga.

No.	Question	Answer
Compared to other international cities, Mississauga is a very well planned city but with little population density. Mississauga suffers from significant urban sprawl. This lack of density makes it difficult to fund high frequency transit routes. Mississauga does occasionally suffer from stormwater related flooding induced by perhaps climate change. According to a fire department representative, there is a need for a more map centric /real-time tracking approach to our emergency operations centre. Policy planning is moving forward to better visualize Mississauga of the future, and future growth		
1	What innovative city applications of technology do you use? Why?	GIS Open Data Infographics Automatic vehicle locating (AVL) Integrated Traffic Network Social Media Engagement Platform Energy + green technology NOTE: some of these are brand new technologies. Many of these technologies are the basis for our work. The alternative of manual operations simply would not be possible. This list is just a small sample of the entire list of applications.
2	What innovative city applications of technologies do you lack right Now?	Map based EOC More flexible enterprise GIS Web based technologies (e.g. blogs, etc.)
3	Does your city try to use technology to increase citizen engagement? How? Which ones?	Social Media / video Engagement software (e.g. bang the table, metroquest) Open data will lead to apps that will facilitate these items you mention below For example smartphones are among the most empowering tools cities are leveraging to get citizens engaged. They let cities do so many things that increase resilience, such as: empowering inhabitants to thesis problems

No.	Question	Answer
		more easily, making cities safer and more responsive; increasing the speed of communication between cities and citizens during major events like disasters; and fueling people-powered local politics in neighborhoods.
4	How does your city leverage technology to improve operational efficiency?	For example, by integrating new technology like the Internet of things, new sensor development and deployment, and new ways to get essential data into the hands of decision makers. Many large business services are managed through business applications Infor MAX – planning and building applications / inspections Avolve – digital plans of submissions TES – traffic network management system SAP (financials / HR) Sharepoint ATG web content management system Etc… there are far too many to list all of them, but these aforementioned systems are the corner stones of our information platform.
5	How do you aggregate and analyze data you already have?	Cities already have access to a lot of data, and over the past few years have been implementing new strategies to use it better. They often don't need to invest in finding new data, but rather in aggregating multiple streams of data in one place to do a multi-dimensional review that looks at how all those streams overlap and connect, in order to draw conclusions that pull from all of them. We use ESRI gis to solve most complex analysis in planning and building. The IT Department is looking at B.I. technologies to unpack and understand Big Data. (e.g. SAP analytics)
6	What new technologies is your city using? Please list these technologies	See #5
7	What software do you use now? ASRI, ARC GIS, BIG DATA, Palantir, ECO-MAPS?	We use ESRI ArcGIS, several modules including spatial analyst, network analyst, 3D analyst, and CityEngine.
8	Do you use technology to fix specific urban problems, like weather tracking to forecast flash floods?	Roads maintenance does use weather tracking for winter events and the forecasting of winter events. SCADA technologies are used for tracking of stormwater.

No.	Question	Answer
9	Which ones you are considering?	NA
10	What is your dream software? Why?	Enterprise GIS, so that all departments can benefit from the idea of one map, thereby increasing the ROI on the initial investment. Once this is fully in place my dream is to model the city as best we can. This modelling will help to forecast and plan for future growth or changes in certain parts of the city. This modelling most of all will help us to understand and unpack the complexity of a city. This modelling will help us to determine if it is better to house for example a logistics company that is large in size and high taxes verses a collection of smaller firms that would house more jobs, but with lesser tax revenue. And is there more revenue generated from the jobs or from the larger logistics firms? We will be able to solve these types of problems once we model the city.
11	Are you using the Big Data and analytics?	See #5
12	Do you agree that "smart cities" are the way of the future? If yes, please list your reasons. If no, please list your reasons.	Totally agree. Analogy: car companies spend millions of dollars on engine diagnosis computers and software. In my view a city is a highly complex engine. We need to do more to monitor this city in order to avoid problems. It also helps to better understand the complex interrelationships between the moving parts, and in doing so will help us to plan for a better future city. And this data and modelling should be interconnected between departments.
13	Do you agree with Smart Cities as an approach to solve your problems?	Yes
14	Do you have any principle concerns about smart technology and its use, such as, Big Data, civic hackers, and the quest for a New Utopia?	No. There are laws in plan to protect us.
15	Do you think that once a city integrates smart technology, the data will be out of your control and therefore create privacy and security issues?	No. See #14
16	What do you think are the primary things smart cities take away from the people who live there?	I think smart cities add value to people’s lives and this will be realized in the future.
17	What do we lose in these sorts of manufactured urban environments?	Absolutely great question. Our downtown is considered a manufactured environment (from a farmers field.) I have been an observer of city design for a better part of my life. Good city design is very difficult. A road that is 1m wider than normal can be the difference between a walkable and non-walkable part of the city. That 1m wider

No.	Question	Answer
		road can also have a significant impact on traffic throughput. I think that understanding this through a modelled city can help to better plan for the future.
18	What are your thoughts about the surveillance implications of smart technology?	I am not too concerned. See #14.
19	Do you thing we voluntarily give up too much information about ourselves by using these technologies.	In some ways yes, but it is the cost of a better future. Recently I bought a car that has a black box (tracks me very much like a jet airliner). This tracking is the cost of finding out what happened during an accident with the spirit of preventing future accidents.
Just a general comment. I am not sure that I am complacent about climate change, but rather that the scope of climate change falls within the Departments of Environment and Public Works Departments.		
a	If you feel a need to streamline data in terms of software usage. Is some of the software you listed legacy - that is, bought some time ago, still used but doesn't mesh with new software	It is not that it is legacy, but rather that it is proprietary. Our goal is to move to a non-proprietary platform (a spatial database) that multiple software platforms can communicate with
b	How are you able to make all the different software work together? Do you see a problem with any of that in daily use?	By doing #(a) yes, all packages can work together.
c	Would another platform be easier if used across the departments?	NA
d	You emphasized that your wish was software to 3D model the city. Why?	So that we can better understand the city. By understanding more, we can plan better.
e	What kinds of things do you want to model?	For us the basic elements like: population, housing, and employment. In addition various landuses and types of employment such as office, population related and industrial. A number of land use related items plus layer on top transportation from our transportation and transit groups
f	What new kinds of useful info are you looking for and why?	A better understand of how the city grows and evolves, and the impact of new developments tracked on top
g	How would it change decision making.	The model would provide sound data and understanding for decision making.

Appendix 2

Ethical Approval Form/ Wolverhampton University/ Faculty of Science And Engineering)
Single response: Ethical Approval Form (Faculty of Science and Engineering)

Survey input field	Respondent's answer
Name: Oruba Alwan	Oruba Alwan

1. Please enter your surname and first name below. (SURNAME, FIRST NAME)
Alwan, Oruba

2. Please enter your University email address (e.g. M.Name@wlv.ac.uk)
o.alwan@wlv.ac.uk

3. Please enter the name of your Director of Studies, Principal Investigator or, for Principal Investigators, your line manager.
Dr.David Hessom

4. Please enter date by which a decision is required below. (Note that decisions can take up to 4 working weeks from date of submission)
February 24th 2015

5. Which subject area is your research / project located?

1. **Architecture and Built Environment**
2. Biology, Chemistry and Forensic Science
3. Engineering
4. Life Sciences
5. Mathematics and Computer Science
6. other

6. Please select your School

1. **School of Architecture and Built Environment**
2. School of Biomedical Science and Physiology
3. School of Biology, Chemistry and Forensic Science

4. School of Engineering
5. School of Mathematics and Computer Science
6. School of Pharmacy
7. Other (please specify below)

7. Does your research fit into any of the following security-sensitive categories? (For definition of security sensitive categories see RPU webpages (www.wlv.ac.uk/rpu) follow links to Ethical Guidance).

1. commissioned by the military
2. commissioned under an EU security call
3. involve the acquisition of security clearances
4. concerns terrorist or extreme groups
5. **not applicable**

8. Does your research involve the storage on a computer of any records, statements or other documents that can be interpreted as promoting or endorsing terrorist acts?

1. YES
2. **NO**

9. Might your research involve the electronic transmission (eg as an email attachment) of any records or statements that can be interpreted as promoting or endorsing terrorist acts?

1. YES
2. **NO**

10. Do you agree to store electronically on a secure University file store any records or statements that can be interpreted as promoting or endorsing terrorist acts. Do you also agree to scan and upload any paper documents with the same sort of content. Access to this file store will be protected by a password unique to you. Please confirm you understand and agree to these conditions?

1. **YES I understand and agree to the conditions**
2. NO (please explain below)
3. I do not understand the conditions

11. You agree NOT to transmit electronically to any third party documents in the University secure document store?

1. **YES I agree**
2. NO I don't agree

12. Will your research involve visits to websites that might be associated with extreme, or terrorist, organisations? (for definition of extreme or terrorist organisations see RPU webpages (www.wlv.ac.uk/rpu) and follow links to Ethical Guidance.

1. YES (Please outline which websites and why you consider this necessary)
2. **NO**

13. You are advised that visits to websites that might be associated with extreme or terrorist organisations may be subject to surveillance by the police. Accessing those sites from university IP addresses might lead to police enquiries. Do you understand this risk?

1. **YES I understand**
2. NO I don't understand

14. What is the title of your project?

THE IMPACT OF EMERGING TECHNOLOGIES IN SUPPORTING URBAN RESILIENCE PLANNING

15. Briefly outline your project, stating the rationale, aims, research question / hypothesis, and expected outcomes. Max 300 words.

Introduction:

Technologies can play a critical role in addressing long & short-comings of existing disaster response operations, which have enabled new possibilities for effectively meeting challenges imposed by man-made and natural disasters. The advances in the use of big data, geographic information systems (GIS) and real-time location tracking systems now mean that decisions can be more effectively made on a wealth of available knowledge and effectively support resilience planning of major cities throughout the world.

With the above in mind, the aim of this research is to develop an initial framework for guidance on best practice for urban resilience planning in Canada. Based on the foregoing, the objectives of the study include:

- A critical review of technologies to support resilience including Big data and Advanced Computing
- A pilot study of a Canadian city planning representatives into their approaches to resilience measures
- Questionnaires and interviews of planning representatives of 3 Major Cities to determine their current practices relating to 'resilience'
- Development of a guide to support resilience implementation measures

In order to achieve the above objectives, four Canadian cities were studied to provide examples and awareness of best practices in resilience, and how implement technologies to support urban resilience planning.

Based on the results of the qualitative questionnaire and semi-structured interviews with each of the cities representatives, an analysis will be undertaken to generate good practices in relation to resilience planning. In particular, this will investigate the use of big data, the use of emerging technologies and the use of existing planning tools. Drawing on this analysis a best practice framework will be developed which will highlight the approaches that need to be taken in order for Canadian (and possibly global) cities to employ in respect to their resilience and disaster management.

16. How will your research be conducted?
Describe the methods so that it can be easily understood by the ethics committee. Please ensure you clearly explain any acronyms and subject specific terminology. Max 300 words

In order to achieve the above objectives, four Canadian cities will be studied to provide examples and awareness of best practices in resilience, and how implement technologies to support urban resilience planning.

Based on the results of the qualitative questionnaire and semi-structured interviews with each of the cities representatives, an analysis will be undertaken to generate good practices in relation to resilience planning. In particular, this will investigate the use of big data, the use of emerging technologies and the use of existing planning tools. Drawing on this analysis a best practice framework will be developed which will highlight the approaches that need to be taken in order for Canadian (and possibly global) cities to employ in respect to their resilience and disaster management.

17. Is ethical approval required by an external agency? (e.g. NHS, company, other university, etc)

1. **NO**
2. YES - but ethical approval has not yet been obtained
3. YES - see contact details below of person who can verify that ethical approval has been obtained)

18. What in your view are the ethical considerations involved in this project? (e.g. confidentiality, consent, risk, physical or psychological harm, etc.) Please explain in full sentences. Do not simply list the issues. (Maximum 100) words)

No significant ethical concerns. Data will be obtained from professionals with knowledge of existing systems, much of which will be in the public domain.

19. Have participants been/will participants be, fully informed of the risks and benefits of participating and of their right to refuse participation or withdraw from the research at any time?

1**.** **YES** (Outline your procedures for informing participants in the space below.
2. NO (Use the space below to explain why)
3. Not applicable - There are no participants in this study

1. Initial telephone call and talk to the City Customer Services regarding the study
2. A brief e-mail of the study aims and objectives sent to relevant representatives. This includes information on the right to refuse participation
3. Meeting (either telecom or physical) with representatives and research again explained and how data will be used as part of the study.

20. Are participants in your study going to be recruited from a potentially vulnerable group? (See RPU website (www.wlv.ac.uk/rpu) and follow link to Ethical Guidance pages for definition of vulnerable groups)
1. YES (Describe below which groups and what measures you will take to respect their rights and safeguard them) 2. **NO**

21. How will you ensure that the identity of your participants is protected (See RPU website (www.wlv.ac.uk/rpu) and follow link to Ethical Guidance pages for guidance on anonymity)
No personal data is collected on the questionnaire / interview. Participants were asked if it was OK to use the city name in the analysis and agreed that this would be OK.

22. How will you ensure that data remains confidential ((See RPU website (www.wlv.ac.uk/rpu) and follow link to Ethical Guidance pages for definition of confidentiality)
Data will be stored on the University one drive and a password protected copy of the responses document stored on my local PC.

23. How will you store your data during and after the project? (See RPU website (www.wlv.ac.uk/rpu) and follow link to Ethical Guidance pages for definition of and guidance on data protection and storage).
Data will be stored as above. Once the study is completed the digital files and work in progress paper copies will be destroyed.

Appendix 3

Pilot questionnaire sent to City of Mississauga

1. What innovative city applications of technology do you use? Why?

2. What innovative city applications of technologies do you lack right Now?

3. Does your city try to use technology to increase citizen engagement? How? Which ones?

4. How does your city leverage technology to improve operational efficiency?

5. How do you aggregate and analyze data you already have?

6. What new technologies is your city using? Please list these technologies

7. What software do you use now? ASRI, ARC GIS, BIG DATA, Palantir, ECO-MAPS?

8. Do you use technology to fix specific urban problems, like weather tracking to forecast flash floods?

9. Which ones you are considering?

10. What is your dream software? Why?

11. Are you using the Big Data and analytics?

12. Do you agree that "smart cities" are the way of the future? If yes, please list your reasons. If no, please list your reasons.

13. Do you agree with Smart Cities as an approach to solve your problems?

14. Do you have any principle concerns about smart technology and its use, such as, Big Data, civic hackers, and the quest for a New Utopia?

15. Do you think that once a city integrates smart technology, the data will be out of your control and therefore create privacy and security issues?

16. What do you think are the primary things smart cities take away from the people who live there?
17. What do we lose in these sorts of manufactured urban environments?

18. What are your thoughts about the surveillance implications of smart technology?

19. Do you thing we voluntarily give up too much information about ourselves by using these technologies.

Appendix 4

Research questionnaire sent to Cities of Toronto, Calgary, Vancouver

1. What innovative city applications of technology do you use? Could you elaborate why you use these technology applications?

2. Do you think that you lack any technological solutions to support city management?

3. Does your city try to use technology to increase citizen engagement? If YES, How does it and which technology is used?

4. How does your city leverage technology to improve operational efficiency?

5. What new technologies is your city using in supporting management of its' infrastructure? Please list these technologies.

6. What software tools are currently used within your organisation for city management? Please specify.

7. Are you considering implementing alternative or additional software tools in the future?

8. If you had the ability to create a piece of software that had any functionality you require what might it look like? Why would these functions be useful?

9. Do you agree that the 3D modeling of the urban environment can support urban resilience planning?

10. Do you agree that "smart cities" are the way of the future? If yes, please list your reasons. If no, please list your reasons.

11. Do you think that once a city integrates smart technology, the data will be out of your control?

12. Do you thing we voluntarily give up too much information about ourselves by using technology at the present time?